145617

000057

BEFORE THE UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION 5

SECTION-BY-SECTION COMMENTS OF KERR-McGEE CHEMICAL CORPORATION

ON THE

ENGINEERING EVALUATION/COST ANALYSIS -- KERR-McGEE RESIDENTIAL AREAS SITE AND PORTIONS OF THE KRESS CREEK SITE IN AND NEAR WEST CHICAGO, ILLINOIS

W.O. Green, III
George B. Rice
KERR-McGEE CHEMICAL CORPORATION
123 Robert S. Kerr Avenue
Oklahoma City, OK 73125
(405) 270-3200

Richard A. Meserve
Herbert Estreicher
COVINGTON & BURLING
1201 Pennsylvania Ave., N.W.
Washington, D.C. 20044
(202) 662-6000

September 16, 1994

TABLE OF CONTENTS

Section-By-Section Comments of
Kerr-McGee Chemical Corporation
On The
Engineering Evaluation/Cost Analysis -- Kerr-McGee
Residential Areas Site and Portions of the
Kress Creek Site In and Near West Chicago, Illinois

A. Comments On The Executive Summary Section Of The Engineering Evaluation/Cost Analysis

- The Engineering Evaluation/Cost Analysis ("EE/CA") asserts that elevated indoor concentrations of thoron and radon and their daughters may be exhibited in some houses as a result of the presence of tailings. EE/CA, ES-1. Tailings threaten to affect indoor decay product concentrations only if a home were built on a substantial volume of tailings or if tailings were used, for example, as backfill around a substantial portion of a foundation. As discussed in Kerr-McGee's Comments on the Action Criteria for Superfund Removal Actions, West Chicago, Illinois and the Associated Fact Sheet (May 29, 1993) (hereinafter "Kerr-McGee Action Criteria Comments"), Kerr-McGee has had extensive experience with the off-site contamination in the West Chicago area as a result of the cleanup of residential properties found within the City of West Chicago ("City") that occurred in the mid-1980s. Id., 9-11, 63-65. Kerr-McGee has rarely encountered properties where a home was built on a substantial volume of tailings or where tailings were used as backfill around a substantial portion of a foundation of the home, and any such properties within the City have already been addressed as part of the cleanup program. Id., 64. Any contamination that may remain at the residential areas within the City is expected to be found in small, isolated pockets that would be highly unlikely to have any consequences on indoor radon or thoron levels. Id. See also id., Exhibit 4 (affidavit of Mark Krippel, ¶ 6 (Mar. 26, 1994)). It thus is extremely unlikely that indoor thoron levels will be found to be significantly different from that which would be expected for ordinary homes in uncontaminated areas.

- Region 5 continues to rely on the Focused Risk Assessment for West Chicago Vicinity Properties (Jan. 1993) (hereinafter "Focused Risk Assessment") to justify its proposed removal program. EE/CA, ES-2, 2-26 to 2-29, 5-2. The Focused Risk Assessment which draws exaggerated conclusions with respect to risk from data collected from a few highly contaminated residential sites was subjected to strong criticisms by the State, the City of West Chicago, and other governmental representatives.[1/] See "Kerr-McGee, West Chicago, Superfund Sites Joint Statement U.S. EPA, Illinois IDNS, Illinois EPA" 3 (March 15, 1993).

[1/] Kerr-McGee's comments provide an extensive discussion of the numerous errors contained in the Focused Risk Assessment. See Comments of Kerr-McGee Chemical Corporation on the Focused Risk Assessment for West Chicago Vicinity Properties and the Associated Fact Sheets (Feb. 25, 1993) (hereinafter "Kerr-McGee Comments on Focused Risk Assessment"). These errors arise from, among other things, EPA's selection of atypical properties to evaluate, its failure to collect sufficient information to characterize the sites, and its use of overly conservative and unsupported assumptions concerning the sites and the potential for exposure to the radiological contamination that may be present at the sites. Id., 3-21.

In response to these criticisms, Region 5 has acknowledged that the Focused Risk Assessment and its findings are "preliminary" and that further data collection and discussion of the various assumptions to be used in preparing a final assessment would be appropriate. See "Notice to Readers" accompanying Summary of Findings West Chicago/Area Preliminary Risk Study (undated). Yet, despite Region 5's recognition of the need for, and its agreement to, collect additional data and to issue a final risk assessment, the preliminary Focused Risk Assessment remains Region 5's only analysis of the potential risks posed by thorium tailings at the residential areas.

Not only has EPA continued to rely on its preliminary risk assessment to justify the proposed removal program, in many places throughout the Engineering Evaluation/Cost Analysis document the Agency improperly has used the data from the preliminary assessment to support decisions concerning the conduct of the removals at the residential area sites. For example, the Engineering Evaluation/Cost Analysis provides an estimate of short-term risks to workers during implementation of the source removal alternative (Alternative 2). EE/CA, 5-2 to 5-4. That estimate is based on the assumption that the volume-weighted average concentration for thorium-232 ("Th-232") and progency is 35 pCi/g. But, that value has been derived from single samples taken from a few highly contaminated properties. The data collected in connection with the Focused Risk Assessment do not accurately reflect the circumstances at the residential area sites and thus cannot be used to estimate the risks to workers from exposure to soils with significantly lower Th-232 concentrations.

- In various places throughout the Engineering Evaluation/Cost Analysis, the screening and cleanup standards that EPA has decided should be applied to the residential area sites are referred to as "applicable or relevant and appropriate requirements ("ARARs")." EE/CA, ES-2, 3-2 to 3-5, Appendix B. By definition, the term ARAR is limited to specific state or federal regulatory requirements that are legally "applicable" or that are "relevant and appropriate" under the circumstances. 40 C.F.R. § 300.5; cf. 42 U.S.C. § 9621(d)(2). But, as demonstrated in Kerr-McGee's comments on the Action Criteria, the cleanup standards cannot properly be considered ARARs. Kerr-McGee Action Criteria Comments, 12-40.[2/] In nearly every instance Region 5 has failed to understand the purpose of the regulations it has deemed to be ARARs and the circumstances in which they were intended to apply. Moreover, even for those regulations that could

---

[2/] See also Letter from R.A. Meserve, Covington & Burling, to R. Frey and D.P. Seely, EPA, Region 5 (Feb. 18, 1994); Letter from R.A. Meserve to R. Frey and D.P. Seely (Oct. 22, 1993); Letter from R.A. Meserve to R. Frey and D.P. Seely (Oct. 5, 1993); Letter from R.A. Meserve to R. Frey and G.M. Schafer (June 2, 1993); Letter from R.A. Meserve to R. Frey (May 5, 1993); Letter from R.A. Meserve to R. Frey and M. Radell (Apr. 28, 1993).

properly be viewed as ARARs, Region 5 has significantly and unjustifiably modified their requirements in establishing its criteria. The modifications are sufficiently significant that the criteria cannot be said to derive from the regulations.

- Region 5 should recast the statements in the Engineering Evaluation/Cost Analysis concerning the origin of the thorium materials in Kress Creek and associated areas. EE/CA, ES-1, 1-4. It has never been demonstrated that Kress Creek and the properties along the Creek have been contaminated by runoff from the West Chicago Rare Earths Facility (hereinafter "Rare Earths Facility" or "the Facility").[3/]

B. Comments On The Introduction Section Of The Engineering Evaluation/Cost Analysis

1. Section 1.1 – General Purpose of an EE/CA

The Engineering Evaluation/Cost Analysis correctly notes that the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"), as amended, limits

---

[3/] A storm sewer passes immediately adjacent both to the portion of the Rare Earths Facility at which processing occurred and to the Facility waste disposal area. The storm sewer discharges into Kress Creek at the point where elevated levels of thorium are first observed. This has led to speculation that materials from the Facility escaped into the storm sewer and that these materials are the source of the thorium contamination of the Creek. But, no theory has ever been advanced that adequately explains the quantity of thorium bearing materials in the Creek. That quantity far exceeds that which seemingly could be accounted for by discharge from the Facility's storm sewer. As a result, there remains substantial uncertainty as to the origins of the thorium materials in Kress Creek and associated areas.

EPA's authority to take only those removal actions that are "appropriate" to address the threat of a release of hazardous substances. EE/CA, 1-1. But, as explained in Kerr-McGee's comments on the Action Criteria, the cleanup program of the residential areas within the City in the mid-1980s has already served to cleanup most properties in the West Chicago area to levels that pose no significant residual risks.[4] See Kerr-McGee Action Criteria Comments, 5-12; id., Appendix A. As a result, the extensive removal program contemplated by EPA cannot be considered "appropriate" or otherwise justified by the need for prompt action to address threats to public health.

2. Section 1.2 – Site Eligibility for EPA Response

Region 5 intends to expand the scope of its removal program to address residential properties along the waterline in the floodplain (but not the channel sediments) of Kress Creek. EE/CA, 1-4. Neither the Focused Risk Assessment, the Action Criteria, nor the various Fact Sheets that Region 5 has issued in the past concerning the removal program address the Kress Creek properties. Even the Work Plan for the Engineering Evaluation/Cost Analysis, which is supposed to

---

[4] Kerr-McGee also has conducted surveys of 139 possibly contaminated properties in DuPage County. Thirty-four (34) DuPage County properties had gamma readings above 30 μR/hr, but in most cases (20 properties) the gamma readings were below 50 μR/hr. Only five properties had gamma readings in excess of 100 μR/hr, and only one property had a reading in excess of 500 μR/hr. See Kerr-McGee Action Criteria Comments, Table at 10.

provide a blueprint for the preparation of the EE/CA, contains no discussion of the Kress Creek properties. See Work Plan for the Engineering Evaluation/Cost Analysis and Remedial Investigation/Feasibility Study -- Kerr-McGee Residential Areas, West Chicago, Illinois (WA 71-5LQV/Contract No. 68-W8-0040) (Feb. 1994) (hereinafter "EE/CA Work Plan"). We question whether Region 5 has established a proper procedural predicate for inclusion of the Kress Creek properties under the current removal program. Despite its misgivings, Kerr-McGee does not object to a limited and focused program that seeks to cleanup the small localized areas of contamination that may be present at properties within the floodplain of Kress Creek.

However, there is no justification for an extensive removal program in the Kress Creek floodplain area. Comprehensive surveys of Kress Creek have been performed by the Nuclear Regulatory Commission ("NRC") and by Kerr-McGee.[5] The data show that the contamination in the Kress Creek area is localized in a few small areas. In

---

[5] In the early 1980s, the NRC staff commissioned a comprehensive survey of Kress by the Oak Ridge Laboratories. P.W. Frame, et al., "Comprehensive Radiological Survey of Kress Creek West Chicago Area, Illinois" (Oak Ridge Associated Universities) (Feb. 1984) (hereinafter "Frame 1984"). The Staff, after reviewing the results of that survey, stated in a letter to counsel for a religious Temple located near the Creek that "the NRC staff does not believe there is an immediate, serious threat to the health and safety of the Temple Community from the contamination along Kress Creek." Letter from Stephen G. Burns, NRC, to Neil T. Proto, Esq. at 2 (Sep. 14, 1984) (with Enclosure) (Exh. 6 to Kerr-McGee Action Criteria Comments).

connection with the Kress Creek Proceeding, Kerr-McGee undertook a systematic survey of the gamma exposure rates for all properties in the vicinity of Kress Creek for which permission to survey could be obtained.[6] The survey staff prepared a map of each property and then surveyed the property along a rectangular grid with a spacing of five feet.[7] Gamma exposure rate readings were made at one meter from the ground surface at each grid intersection using an Eberline PRM-7 gamma meter. Any readings in excess of 30 μR/hr were recorded on the map of the property.

The survey data provide detailed information as to the gamma field along the Creek. In particular, the measurements enable not only the identification of points with elevated gamma readings, but also the areal extent and distribution of regions with elevated readings. This was accomplished by using the grid measurements to construct isopleths defining the contours of the gamma radiation field.

---

[6] See Appendix B to "Testimony of John A. Auxier, Douglas B. Chambers, and Edwin T. Still on the Risks Associated With the Presence of Thorium-Containing Materials Along the Kress Creek Area and With Their Cleanup," in Kerr-McGee Chemical Corp. (Kress Creek Decontamination), Dkt. No. 40-2061 SC, ASLBP No. 84-502-01-SC (Mar. 31, 1986) (Attached At Tab A). The survey was undertaken for property adjacent to the Creek from the storm-sewer outfall to the confluence with the West Branch of the DuPage River. Permission to survey was obtained for 22 of the 28 properties along the Creek, or approximately 80% of all properties.

[7] In the case of certain of the non-residential properties, such as the park areas, the survey grid had a spacing of ten feet in the vicinity of the Creek. The larger spacing was used because these properties were largely unaffected.

Table 1 sets out the total area from all the surveyed properties that were found to have radiation intensities from 50 to 99 μR/hr, from 100 to 149 μR/hr, and greater than 150 μR/hr.

TABLE 1

TOTAL AREA OF ELEVATED GAMMA REGIONS

	Total Area (ft^2)	Percentage of Total Area With Readings Greater Than 50 μR/hr	Percentage of Total Area Surveyed
50 to 99 μR/hr	44700	88.3	1.40
100 to 149 μR/hr	4300	8.5	0.13
≥ 150 μR/hr	1600	3.2	0.05

As may be seen, the vast preponderance of the regions with gamma intensities greater than 50 μR/hr were found to have a gamma intensity in the lowest intensity range (50 to 99 μR/hr). In fact, only about three percent of the properties with gamma intensities in excess of 50 μR/hr were found to have an intensity greater than 150 μR/hr. And the percentage of the total area along the Creek that has elevated readings (above 50 μR/hr) is minuscule.[8/] The data thus

[8/] The total area of the surveyed properties is about 3,200,000 ft^2. Thus the total area with gamma readings in excess of 50 μR/hr -- about 50,600 ft^2 -- represents approximately 1.6% of the total area surveyed. The total area with readings in excess of 150 μR/hr constitutes only 0.05% of the total area surveyed.

confirm that markedly elevated gamma readings affect only a slight portion of the area along the Creek.

The maps also show that the regions with elevated readings are isolated from each other. Table 2 sets out information as to the size of the regions along the Creek for which elevated gamma readings were observed.

TABLE 2

AREA OF INDIVIDUAL ELEVATED GAMMA REGIONS

	Minimum Area (ft^2)	Average Area (ft^2)	Maximum Area (ft^2)
50 to 99 μR/hr	100	2000	6600
100 to 149 μR/hr	150	500	1500
$\geq$ 150 μR/hr	100	450	600

The regions that have a gamma intensity of 150 μR/hr or greater were observed to have an average area of 450 ft^2, and the maximum area of any such region was only 600 ft^2. The data thus confirm that the most elevated gamma readings affect only small and discrete regions in the Creek vicinity.

There thus is no justification for an extensive removal program in the Kress Creek Area. To the extent Region 5 contemplates a removal program beyond that needed to address the few area "hotspots" that have been identified, we suggest that the Agency defer action until the RI/FS that is planned for the Creek area is completed. Any plans to conduct excavations below the water table, for example, would require careful analysis and a full consideration of alternatives.

3. <u>Section 1.4 – Regulatory Strategy</u>

Region 5 proposes to undertake the cleanup of the West Chicago residential sites under the guise of a "non-time-critical removal action." EE/CA, 1-5 to 1-7. Removal actions are intended to be limited to short-term, relatively inexpensive activities. <u>See</u> 42 U.S.C. § 9604(c) (limiting fund financed removal actions to $2 million or 12 months in duration). <u>See also</u> 40 C.F.R. §§ 300.415(d)(1), (4), (5), (6), (7) (exemplary list of removal activities all of which relate to responses that can be taken quickly and at low cost). Yet, the costs of the West Chicago residential cleanup (which is estimated at between $22 million to $119 million, depending on the volume of material to be excavated), far exceed the costs incurred in any other removal program of which we are aware.

Kerr-McGee has provided extensive comment on whether the proposed removal is consistent with EPA authority under the National Contingency Plan ("NCP"). <u>See</u> <u>Kerr-McGee Action Criteria Comments</u>, 5-12. The <u>Engineering Evaluation/Cost Analysis</u> provides no recognition of, or response to, the issues Kerr-McGee has raised on these matters. We justifiably expect that Region 5 will address these issues in the responsiveness document that is to be prepared in connection with the <u>Engineering Evaluation/Cost Analysis</u>.

4. <u>Section 1.4.1 – Removal as an Early Action</u>

The Engineering Evaluation/Cost Analysis reports that after the removal program has been completed, EPA intends to conduct a final remedial investigation/feasibility study ("RI/FS") to determine whether further remediation of the off-site areas is warranted. ES, 1-7, 3-1. The cleanup criteria that EPA has selected for the removal program already are significantly more stringent than the standards that have guided every other cleanup of similar sites of which we are aware. See Kerr-McGee Action Criteria Comments, 61-62. There thus can be no real prospect that any residual risks that may remain at the conclusion of the cleanups would warrant further action.

Moreover, Kerr-McGee strenuously objects to any implication that the residential properties might be subject to further cleanups. Most of the contaminated properties were already subject to extensive remediation in the mid-1980s and the EPA removal program would be the second such cleanup program conducted in the area. There can be no conceivable justification for subjecting the residential areas to a third-round of cleanups, particularly if EPA plans to pass the costs on to others.

5. <u>Section 1.4.2 – Investigation and Removal as Concurrent Activities</u>

The Engineering Evaluation/Cost Analysis explains that removal actions will be undertaken only where evidence of contamination related to thorium tailings exceeding the discovery criteria is found. EE/CA, 1-8. Properties with elevated radiological readings that are attributable to conditions or other radioactive materials not related to the Rare Earths Facility are not to be subject to removal action. Id. But, nowhere in the document does Region 5 explain how it will assure that only sites contaminated by tailings are remediated.[9/] The procedures to guide this important threshold determination should be carefully thought through and presented for comment.

With respect to indoor radon levels, the EPA screening program may well result in a large number of false positives -- determinations that the radon limit is exceeded, but for which no response under CERCLA is appropriate. Data collected by the Illinois Department of Nuclear Safety ("IDNS"), and submitted by Kerr-McGee with its comments, show that 25-50 percent of the homes in DuPage County have levels

---

[9/] Region 5 has suggested in the EE/CA Work Plan document that a property will be a candidate for no removal action, without further soil sampling or in-situ measurements, only "if gamma scan results over the entire property do not exceed background, and indoor Rn/Tn and indoor gamma indicates no contamination." EE/CA Work Plan, 1-26. This criterion fails to include recognition that only elevated readings resulting from tailings can justify cleanup. And, unless the expected variability in both outdoor and indoor background gamma levels and in indoor radon levels is accounted for in the measurements, (see Kerr-McGee Action Criteria Comments, 21-23, 33-33, 37-38) extensive soil sampling may be required before a property is deemed sufficiently clean to warrant no removal action.

of radon that exceed EPA action levels (4 pCi/L).[10/] A substantial number of homes in West Chicago thus are expected to have elevated indoor radon levels for reasons entirely unrelated to the presence of tailings.

Once levels that exceed the screening level are found, however, Region 5 will have to undertake detailed further sampling to determine the cause of the readings. The affected homeowners, many of whom have exaggerated fears of the hazards of the West Chicago tailings, may well demand exhaustive further sampling and, in any event, will likely be suspicious of any ultimate determination that tailings are not the cause of elevated readings. We believe that the program that Region 5 envisions will cause substantial anxiety in the local areas, with resulting substantial impacts on the local community. Moreover, the confirmatory sampling could be intrusive -- i.e., drilling through basement floors -- and restoration of the affected properties very expensive.[11/]

The ability to measure and distinguish between radon and thoron decay products becomes critical to a determination of the cause of elevated indoor radon/thoron measurements

---

[10/] See Letter from R.C. Whitcomb, IDNS, to M. Krippel (Jan. 17, 1992) (Exh. 22 to Kerr-McGee Action Criteria Comments).

[11/] In our view, this fear and cost are completely needless. The West Chicago tailings are predominantly thorium-chain materials; radon-220 is less likely to diffuse into a house than radon-222 in light of its shorter half life and, in any event, radon-220 poses a lesser health risk than radon-222. Kerr-McGee Action Criteria Comments, 27-29.

(tailings or natural materials). As we understand, Region 5 has selected the R.A.D. M-1 Surveymeter radon progeny integrating sampling unit (RPISU) for use in the discovery phase of the removal program. EE/CA Work Plan, 2-9. But, the Agency has not shared with the public the data which demonstrates that the RPISU is an appropriate methodology for accurately measuring and distinguishing between radon and thoron decay products. Nor has Region 5 explained how the differences in diffusion lengths between radon and thoron and the resulting differences in indoor radon and thoron daughter concentrations are to be taken into account in the measurements.[12/] In addition, because only short term sampling (7 to 10 days) is contemplated (EE/CA Work Plan, 2-10), there is likely to be substantial unreliability in any such measurements.[13/]

[12/] For a typical home built on soil containing equal concentrations of uranium and thorium, the concentrations of daughters of radon-222 (a uranium daughter) in the home would be nearly a factor of 30 greater than the concentration of daughters of thoron (radon-220, a thorium daughter). See Kerr-McGee Chemical Corp. (Kress Creek Decontamination), LBP-86-18, 23 NRC 799, 802 (1986), aff'd on other grounds, ALAB-885, 27 NRC 59 (1988). This result stems from the very different half-life of thoron (55 sec.) from that of radon (3.83 days). Because of its short half-life, thoron has a relatively small diffusion length in soil (80 times smaller than radon) and only the very near surface of contaminated soil can release thoron into the crawl space or basement of a home built on thorium-containing soil.

[13/] See Nero, et al., Indoor Radon and Decay Products: Concentrations, Causes, and Control Strategies, 42 (DOE/ER-0480P) (Nov. 1990) (Exh. 26 to Kerr-McGee Action Criteria Comments) (reporting that "in the same building there is often a substantial variation [of radon concentrations]
(continued...)

C. Comments On The Site Characterization Section Of The Engineering Evaluation/Cost Analysis

1. Section 2.1 – Background

The history of the ownership of the Rare Earths Facility recited in the Engineering Evaluation/Cost Analysis fails to reflect the ownership of the Facility by the American Potash and Chemical Company during the period 1958 to 1967.

2. Section 2.3.1 – Residential Areas Site

The Engineering Evaluation/Cost Analysis asserts that extensive deposits of contaminated materials may be present at residential properties within the City. EE, 2-9. But, for the reasons discussed in Kerr-McGee's comments on the Action Criteria, extensive deposits of contaminated material are highly unlikely to be present at these properties. Kerr-McGee Action Criteria Comments, 2-10. Some 2,726 properties in the City of West Chicago were surveyed in the mid-1990s and 116 of the 117 properties that exceeded the cleanup criteria (30 μR/hr) were remediated to approximate background levels. There thus is no reason to believe that

---

[13] (...continued)
with time on various temporal scales, i.e., season-to-season, week-to-week, and on a daily or hourly basis"). The National Council on Radiation Protection And Measurements ("NCRP") has observed that "[v]alid exposure measurements can only be obtained with long term follow-up of integrating measurements or several measurements of a week's duration taken during a minimum of two seasons per year." NRCP, Measurements of Radon and Radon Daughters in Air, 122 (1988) (Report No. 97) (Exh. 27 to Kerr-McGee Action Criteria Comments).

any City properties with extensive contamination were not addressed during the earlier cleanup.

3. Section 2.2.8 – Natural Background Radiation

- The Engineering Evaluation/Cost Analysis estimates that background gamma levels for the West Chicago area range between 5 microRoentgen per hour (μR/hr) and 13 μR/hr. EE/CA, 2-6. In point of fact, the variability in natural background in the area is significantly higher. An Argonne National Laboratories study of the residential areas reports that "[t]he external natural-radiation background in this area varies from 12 to 36 μR/hr, with about 95% of the values ranging between 14 and 25 μR/hr."[14/] The authors of that study attribute the high natural background to the fact that the soil in the area is higher in uranium, thorium and their daughters than many other soils in Illinois as a result of phosphate fertilization and the use of water with high natural radioactivity.[15/] Id., 2.

- The Engineering Evaluation/Cost Analysis incorrectly estimates the background indoor thoron and radon decay product

---

[14/] Frigerio, et al., "Thorium Residuals in West Chicago, Illinois," 2 (Argonne National Laboratories) (NUREG/CR-0413, ANL/ES-67) (Sept. 1978) (hereinafter "Frigerio Report") (Exh. 3 to Kerr-McGee Action Criteria Comments).

[15/] The observed variability in natural background is not atypical and is expected for an area the size of West Chicago. The background gamma field in Washington, D.C., for example, ranges from 8 μR/hr to greater than 53 μR/hr, depending on location. See Mark, Variability of Natural Background Radiation, 19-20 (Advisory Committee on Reactor Safeguards, U.S. Nuclear Regulatory Commission) (Sept. 1988) (Exh. 11 to Kerr-McGee Action Criteria Comments).

concentrations for the residential areas at 0.002 working levels (WL).[16/] EE/CA, Table 3-1 at 3-4. Several studies have shown that radon concentrations in the West Chicago area are elevated for reasons unrelated to tailings and that as many as 50 percent of the homes in the area are likely to have decay product concentration that are 10 times higher than the 0.002 WL estimate provided in the Engineering Evaluation/Cost Analysis.[17/]

- The Engineering Evaluation/Cost Analysis has not provided an estimate of background indoor gamma levels. See EE/CA, Table 3-1 at 3-4 (noting that background data for indoor gamma exposure rates are unavailable). We assume that the background level will be determined prior to the commencement of the discovery phase of the project and that the data supporting the estimate will be made available to the public.

16/ The working level (WL) is defined as that concentration of radon daughters which has a potential alpha energy release of 1.3×10^5 MEV per liter of air.

17/ IDNS has reported that from 25 to 50 percent of the homes in DuPage County have radon concentrations exceeding 4 pCi/L (roughly 0.02 WL). Letter from R.C. Whitcomb, IDNS, to M. Krippel (Jan. 17, 1992) (Exh. 22 to Kerr-McGee Action Criteria Comments). The circumstances in DuPage County parallel those found in other parts of Illinois and the United States generally. See IDNS, Radon in Illinois: A Status Report, Fig. 7 (1990 Update) (Exh. 23 to Kerr-McGee Action Criteria Comments); White, et al., "Indoor ^{222}Rn Concentrations In A Probability Sample of 43,000 Houses Across 30 States," 62 Health Physics 41, 49 (1992) (Exh. 25 to Kerr-McGee Action Criteria Comments) (21 percent of all houses undergoing screening measurements had radon concentrations exceeding 4 pCi/L).

Any effort to determine background indoor gamma levels must reflect recognition of the fact that indoor gamma levels might be artificially raised by the use of construction materials that contain naturally occurring radiological material. Studies have shown that indoor gamma exposure rates may vary extensively depending on the type of construction material that was used in building the home. For example, the NCRP has shown that indoor gamma levels can vary from 24 mrad/y in frame houses to 40 mrad/y in brick houses relative to an outdoor exposure rate of 35 mrad/y.[18/] Others have observed that concrete blocks with elevated radioactivity can increase indoor exposure rates by 10 μR/hr or more.[19/]

4. Section 2.3.2 – Relevant Portions of the Kress Creek Site

Region 5 has not considered all of the data available on Kress Creek and has failed to carefully scrutinize the limited data on which the Engineering Evaluation/Cost Analysis has relied. EE/CA, 2-10 to 2-11. The Engineering Evaluation/Cost Analysis relies extensively on sampling conducted for the NRC staff by Oak Ridge Associated Universities ("ORAU") as the source of information concerning

---

18/ NCRP, Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake By Man of Radionuclides Released to the Environment, 82-84 (1984) (Report No. 76) (Exh. 19 to Kerr-McGee Action Criteria Comments).

19/ See Kahn, et al., "Search for Building Materials As Sources of Elevated Radiation Dose." 45 Health Physics 349 (1983) (Exh. 21 to Kerr-McGee Action Criteria Comments).

the concentrations of thorium-containing materials in and along the Creek.[20] An NRC panel of administrative law judges has carefully reviewed the ORAU data and has concluded that there is considerable uncertainty surrounding the sampling results. Kerr-McGee Chemical Corp. (Kress Creek Decontamination), LBP-86-18, 23 NRC 799, 817-21 (1986), aff'd on other grounds, ALAB-885, 27 NRC 59 (1988) (Attached at Tab B). The NRC found that because the confidence interval for the data is skewed (i.e., the 95% confidence interval around a measurement of 10 pCi/g, for example, ranges from 4 pCi/g to 30 pCi/g), the errors in the survey may tend to distort the averages upward. 23 NRC 819. The NRC also found that there were large statistical variations in the thorium-in-soil data which had not been adequately accounted for in the ORAU Report. Id.

The Engineering Evaluation/Cost Analysis also relies on the ORAU Report for data on gamma exposure rates in the area. EE/CA, 2-11. But, there are significant problems with the ORAU gamma measurements as well. For example, ORAU reported that the normal background rate in the area is approximately 8.6 μR/hr. Studies by other NRC contractors, however, have found that the background gamma rates for the area are considerably higher. For example, an Argonne National Laboratories Study of the area reports that "[t]he external natural-radiation background in this area varies from

[20] Frame (1984), supra note 5.

12 to 36 μR/hr, with about 95% of the values ranging between 14 and 25 μR/hr."[21] There thus is considerable uncertainty as to the baseline against which to judge the exposure rates reported in the ORAU Report.

And finally, the Engineering Evaluation/Cost Analysis has ignored a comprehensive gamma survey of the properties in the vicinity of the Creek that was undertaken by Kerr-McGee in connection with the Kress Creek proceeding. See supra, pp. 7-10. The properties were surveyed on a rectangular grid with a spacing of five feet (on some downstream properties a 10-foot grid was used) and readings in excess of 30 μR/hr were recorded on a map of each property.[22] The total area of the regions with gamma readings in excess of 50 μR/hr was only about 2.0 percent of the total area surveyed. Only 2.4 percent of the total area with readings in excess of 50 μR/hr was found to exceed 150 μR/hr. Moreover, the maximum area of any region yielding gamma readings in excess of 150 μR/hr was only 600 ft^2. This study thus reveals that regions with elevated exposure rates are small in areal extent and are infrequently encountered.

[21] Frigerio Report, supra note 14, at 2. See also 23 NRC 819.

[22] By contrast, the ORAU Survey was undertaken at 50 meter increments as measured along the length of the Creek.

5. <u>Section 2.4.1.1 – Radiological Contaminants</u>

Region 5 plans to investigate the degree of equilibrium between Uranium-238 ("U-238") and its decay products in residential area soils by analyzing soil samples that are to be collected from Kress Creek, Reed-Keppler Park, and the Sewage Treatment Plant. EE/CA, 2-12. However, no explanation is provided as to why samples will not be taken from the residential areas themselves. It would seem that analysis of soils from the residential areas would provide the most direct correlation between U-238 and daughter equilibrium concentrations in residential area soils.

6. <u>Section 2.4.1.2 – Metal Contaminants</u>

- The <u>Engineering Evaluation/Cost Analysis</u> incorrectly reports that the Rare Earths Facility may have significant sources of metal contamination other than those generated from ore processing. EE/CA, 2-15. The metals that are present in the tailings pile are at the levels that are typical of the natural ore from which the tailings were produced. There thus is no reason to believe that the presence of metals in the Facility wastes are derived from sources other than the natural ore that was feed to the process.

- The <u>Engineering Evaluation/Cost Analysis</u> correctly reports that Reed-Keppler Park was used as a landfill with multiple waste generators. EE/CA, 2-15. Indeed, much of the waste disposal that may have occurred at Reed-Keppler Park has not been attributed to the Rare Earths Facility.[23/] Nonradiological contaminants identified in soil samples collected from within the fenced security area include semivolatile organic compounds ("SVOCs") and pesticides, compounds not identified in Facility soils or groundwater. Indeed, U.S. EPA's own contractor has concluded:

> "[T]he non-radiological contamination found in the soil samples is likely associated with municipal solid wastes and not related to the thorium mill tailings. SVOCs are commonly found as incomplete combustion products of organic materials and are often associated with coal tar, motor oil, and asphalt. Some SVOCs are also used as plasticizers. The pesticides may be associated with landfill activities or with historical surface application."

Id.

- Region 5 has not adequately explained why barium and chromium are considered potential contaminants of concern even though the data show that neither metal will exceed its respective risk-based concentration. EE/CA, 2-16. The decision to include barium and chromium as potential contaminants of concern appears to be based on EPA's incorrect decision to include barium and chromium in the hazard ranking score ("HRS") for the off-site areas. EE/CA, 2-21. But, the HRS is intended to provide a ranking of hazardous waste sites for the purpose of determining whether to include the sites on

---

[23/] CH_2M-Hill, Work Plan for the Remedial Investigation/Feasibility Study Kerr-McGee Reed-Keppler Park, West Chicago, Illinois, 1-10 (WA 50-5FQT/Contract 68-W8-0040) (Oct. 5, 1992).

the National Priority List ("NPL") and is not intended to guide the conduct of removal actions.

7. Section 2.4.2 – Conceptual Site Model

The Engineering Evaluation/Cost Analysis correctly notes that because of its extremely short half-life (55 sec.), the potential for migration of thoron into a home is low. EE/CA, 2-20. The Engineering Evaluation/Cost Analysis goes on to report that once thoron enters a home through foundation cracks or sumps, its decay product, lead-212 ("Pb-212"), may persist in the home for some time and may migrate from the entry point. Id. The Engineering Evaluation/Cost Analysis has failed to note, however, that because of the relatively small diffusion rate for thoron (80 times smaller than radon) only the very near surface of contaminated soil can release thoron into the crawl space or basement of the home. As a consequence, only an extremely small fraction of the thoron emitting from the tailings will enter the residence in the first instance. Moreover, much of the Pb-212 that would be generated is likely to be removed from the air by mechanisms such as plate-out (electrostatic attraction to walls and other surfaces) and thus becomes unavailable for exposure to the resident.

D. <u>Comments On The Identification Of Removal Action Alternatives Section Of The Engineering Evaluation/Cost Analysis</u>

1. <u>Section 4.1.5 – Treatment</u>

Region 5 has declined to endorse soil separation of excavated soils from the off-site areas as a treatment option. EE/CA, 4-10. Kerr-McGee urges the Agency to modify its assessment. Although Kerr-McGee does not expect that soils from shallower excavations of off-site properties will be suitable for screening, soils from deeper excavations may contain sufficiently clean materials so as to justify soil separation. Soil separation may offer significant reductions in the volumes of the soils that would need to be transported off-site for disposal and should be retained as a treatment option. Indeed, Kerr-McGee's analysis of the feasibility of soil separation indicates that the separation of course soil fractions with concentrations below 5 pCi/g total radium from more highly contaminated material is technologically feasible and economically attractive.

Volume reduction achieved by soil separation provides substantial societal benefits. As Region 5 is well aware, space in waste depositories is increasingly scarce. No health or safety benefit is achieved by requiring material that can be separated from contaminants by soil separation to be disposed of in permanent depositories. Moreover, volume reduction offers additional benefits by reducing non-radiological risks resulting from transportation of large volumes of material to a distant off-site depository. And it offers significant benefits in terms of both ease of remediation and lowering of the expense of transportation and disposal. Moreover, U.S. EPA itself has endorsed the use of volume-reduction as an innovative technology for the cleanup of Superfund sites containing radiological material.[24]

And finally, it should be recognized that after the off-site materials are brought to the Facility, the materials fall under the licensing authority of the IDNS. The IDNS will oversee and control all actions taken with respect to the manner in which the materials are processed, stored, and managed at the Facility. The IDNS is fully competent to make these decisions and Region 5 should rest assured that the IDNS will exercise its licensing authority in a manner that is fully protective of the public health and safety and the environment.

2. Section 4.1.6 – Interim Storage

- Although interim storage of off-site soils at the Rare Earths Facility has been retained as an alternative for further consideration, Region 5 has not yet endorsed interim storage for use in the removal program. We urge Region 5 to do so.

---

[24] See EPA, Technological Approaches To The Cleanup Of Radiologically Contaminated Superfund Sites (EPA/540-2-88/002) (Aug. 1988).

Region 5 has imposed two conditions on the acceptability of the Facility for interim storage of off-site soils. The storage period must be temporary (up to 1 year) and the off-site soils must be segregated from the other Facility wastes. EE/CA, 4-11. Both conditions are readily satisfied. The storage of the materials at the Rare Earths Facility will indeed be temporary. As off-site soils arrive at the Facility, they will be placed in stockpile(s). The residence time of the materials in the stockpile(s) will be monitored, and each stockpile will be removed within six months from the date on which it was established.

In addition, if the Facility is used for shipment of the CERCLA wastes, Kerr-McGee has no objection to segregating soils from the West Chicago Superfund sites from other Facility materials. However, it should be understood that Kerr-McGee does not intend to establish a separate stockpile for each load of off-site materials that is received at the Facility. It also should be understood that the off-site soils will likely be blended with other Facility soils for shipment.

- The Engineering Evaluation/Cost Analysis refers to contaminated soils from the Rare Earths Facility and other "Kerr-McGee sites." Id. To the extent the reference to other Kerr-McGee sites is intended to refer to the other NPL-listed sites (i.e. the Sewage Treatment Plan or Reed Keppler Park), Kerr-McGee strenuously objects to the designation of these other off-site areas as "Kerr-McGee" sites. Kerr-McGee is not the owner (and has never been the owner) of these off-site areas. Kerr-McGee also is not a "responsible party" under CERCLA § 107, 42 U.S.C. § 9607, with respect to these areas. Kerr-McGee understands that the tailings found at most of the West Chicago properties were removed from the Rare Earths Facility by various residents, contractors, or others in the 1930s and 1940s. See Frigerio Report, supra note 14, at 4. (Kerr-McGee became the owner of the Facility in 1967 as a result of a corporate acquisition.) Apparently the Facility was viewed by the community as a source of fill material. The Kerr-McGee connection to the off-site contamination is too attenuated to provide a foundation for liability.

The only conceivable theory by which Kerr-McGee might be deemed liable as a responsible party is that it somehow "by contract, agreement or otherwise arranged for disposal . . . or arranged with a transporter for transport for disposal . . . ." Id., § 9607(a)(3). In circumstances in which tailings were placed on the off-site areas by third parties without involvement by Kerr-McGee, Kerr-McGee cannot be deemed to have arranged for disposal.

Moreover, Section 107 of CERCLA provides:

> There shall be no liability under subsection (a) of this section for a person otherwise liable who can establish by a preponderance of the evidence that the release or threat of release of a hazardous substance and the damages resulting therefrom were caused solely by --

. . .

> (3) an act or omission of a third party other than an employee or agent of the defendant, or than one whose act or omission occurs in connection with a contractual relationship, existing directly or indirectly, with the defendant . . . if the defendant establishes by a preponderance of the evidence that (a) he exercised due care with respect to the hazardous substance concerned, taking into consideration the characteristics of such hazardous substance, in light of all relevant facts and circumstances, and (b) he took precautions against foreseeable acts or omissions of any such third party and the consequences that could foreseeably result from such acts or omissions.

Id., § 9607(b). The disposition of the tailings at off-site properties results from the actions of third parties who were not employees or agents of Kerr-McGee's predecessors and who had no direct or indirect contractual relationship with Kerr-McGee's predecessors. In light of the fact that no one was aware of the potential hazards associated with tailings at the time, Kerr-McGee's predecessors exercised due care with respect to the tailings and took adequate precautions against the foreseeable acts and omissions of third parties.

In short, the straightforward application of Section 107 shows that Kerr-McGee cannot be held liable under CERCLA for costs or damages associated with the West Chicago Superfund Sites. The reference to these sites as "Kerr-McGee sites" is thus unfair and inaccurate.

3. <u>Section 4.1.7 – Disposal</u>

The discussion in the Engineering Evaluation/Cost Analysis concerning Envirocare's readiness to accept shipments of Section 11(e)(2) byproduct material is outdated. EE/CA, 4-12. The first railcar of tailings destined for disposal at the Envirocare site left the Rare Earths Facility on September 9, 1994.

4. <u>Section 4.1.8 – Recontamination Prevention</u>

Region 5 has retained for further consideration the installation of a barrier wall of sheet piling along the banks of Kress Creek to prevent possible recontamination of Kress Creek properties during severe flooding events. EE/CA, 4-5, 4-13. The conceptual design calls for some 5200 feet of steel sheet piling to be driven to a depth of roughly 9 feet below the surface. Id., 4-20 to 4-21. Region 5 has estimated that the incremental cost for the sheet piling will be at least $1.5 million. Id., 5-18 to 5-19. Although Region 5 has retained this option for further consideration, the Engineering Evaluation/Cost Analysis aptly demonstrates that sheet piling would be expensive, would be difficult to implement administratively, would cause dissention within the local community, and is largely unnecessary given the extremely low probability of a storm/flooding event of sufficient severity and magnitude to cause a significant deposition of contaminated sediments.

5. Section 4.3.2 – Packaging and Transportation

The Engineering Evaluation/Cost Analysis contemplates that the excavated soils from residential properties are to be packaged in polypropylene bags for shipment to the Rare Earths Facility. EE/CA, 4-17. Any requirement for packaging of excavated soils is unnecessary and impracticable. Extensive experience gained during the West Chicago cleanup program in the mid-1980's provides ample demonstration of the safety and practicality of bulk shipment of excavated soil. During the prior cleanup, excavated soils were loaded into tarpaulin-covered trucks with the tailgates of the trucks sealed to prevent spillage. This method of transport was safely used to return roughly 35,000 cubic yards of soil to the Facility for storage without a single incidence of spillage.

The use of polypropylene bags would serve to increase costs, require the utilization of a greater number of trucks for transporting the soils to the Facility and a greater number of railcars for transhipment to Envirocare, and cannot be justified on the basis of public health and safety.

6. Section 4.3.5 – Conceptual-Level Description of the Interim Storage Contingent Action

The Illinois Uranium and Thorium Mill Tailings Control Act has recently been amended. EE/CA, 4-19. (A copy of the Act as amended is attached at Tab C.)

E. Comments On The Evaluation Of Alternatives Section Of The Engineering Evaluation/Cost Analysis

1. Section 5.1.1.1 – Alternative 1

For the reasons discussed above (pp. 2-4, supra), any reliance on the preliminary Focused Risk Assessment to assess potential health impacts of the no-action alternative (Alternative 1) is improper. EE/CA, 5-2.

2. Section 5.1.1.2 – Alternative 2

- The Engineering Evaluation/Cost Analysis compares the potential dose to residents from removal activities to the 10 mrem/yr standard for airborne releases found in the National Emission Standard Hazardous Air Pollutants ("NESHAPs") at 40 C.F.R. part 61, subpt. I. EE/CA, 5-3. The NESHAP by its terms applies to radionuclide emissions from NRC-licensed facilities only. 40 C.F.R. § 61.100. The comparison to the NESHAP in the context of the residential site cleanup thus is improper; the NESHAP simply does not apply to residential sites.

3. Section 5.1.1.3 – Alternative 2, Contingent Action A -- Interim Storage

- Kerr-McGee supports the proposed use of the Rare Earths Facility as a site at which soils excavated during the removal program could be stored until they are shipped for disposal to Envirocare. EE/CA, 5-4 to 5-5. In our view, the only sensible approach, as Region 5 has recognized, is the use of the Rare Earths Facility for storage and shipment. Any other location will inevitably involve the costs associated with duplicating the loading facilities that have already been constructed at the Rare Earths Facility for the shipment of the Facility wastes. These costs would include construction of rail siding and a loading facility, installation of any necessary access roads, and the potential for contaminating a now clean area with tailings.

- In the discussion of the incremental dose to the nearest resident from interim storage at the Rare Earths Facility reference is made to a regulatory limit of 50 mrem/yr. EE/CA, 5-4. The reference appears to be in error. The relevant NRC limit is 100 mrem/yr. 10 C.F.R. § 20.1301 (1993).[25]

4. Section 5.1.1.4 – Alternative 2, Contingent Action B -- Off-Rare Earths Facility Staging Area

- Region 5 has retained as a contingent action the transportation of excavated soils to a railspur and staging area at some unidentified site other than the Rare Earths Facility (Alternative 2, Contingent Action B). EE/CA, 4-15, 4-19 to 4-20, 5-5. This alternative is unnecessary. Kerr-McGee has received the necessary approvals from the IDNS

---

[25] The NRC does allow a demonstration of the satisfaction of this limit by a showing that the total effective dose does not exceed the limit or assuring that the dose from gaseous and liquid effluents and from external sources each is less than 50 mrem/yr. 10 C.F.R. § 20.1302(b). This latter optional method of demonstrating compliance does not change the applicable limit.

to permit the interim storage of off-site soils at the Facility. See Condition 52 to Amendment No. 23 to IDNS License Number STA-583 (September 1994) (authorization to receive up to 15,000 cubic yards of off-site residential soil during 1994 at the Rare Earths Facility) (Attachment to Letter from R.A. Meserve to E. Deamer (Sept. 16, 1994)). Moreover, a railspur and loading facility has already been constructed at the Facility and shipments are now occurring.

5. Section 5.1.2.2 – Protection of the Environment -- Water

The Engineering Evaluation/Cost Analysis asserts that runoff from the Rare Earths Facility may have impacted surface water and storm sewer conveyance facilities. EE/CA, 5-6. That assertion is misguided. All surface runoff from the Kerr-McGee Facility is contained within the Facility boundaries. There is no basis for believing that Facility runoff has impacted sewer conveyance facilities.

6. Section 5.2.2 – Administrative Feasibility

Inexplicably, the authors of the Engineering Evaluation/Cost Analysis have failed to identify the permits and regulatory requirements that must be secured before an off-Rare Earths Facility railspur and staging area can be established. EE/CA, 5-11. Construction of the railspur and staging area would require, at a minimum, issuance of construction permits from local authorities and presumably would require licenses or approvals from IDNS and other State agencies.

F. Comments On The Application Of ALARA Section Of The Engineering Evaluation/Cost Analysis

The November 1993 Action Criteria added a new element to the cleanup criteria for the residential area sites that was not part of the draft proposal. The Action Criteria now provides that, in addition to the specific numerical cleanup criteria, all cleanup activities must comply with the additional requirement that "[e]very reasonable effort should be made to maintain radiation exposures, and the amount of radioactive materials in unrestricted areas, to levels that are as low as is reasonably achievable (ALARA)." Action Criteria, 11.

Kerr-McGee objects to the addition of a significant new element to the cleanup criteria without any opportunity for affected parties to comment. We are also troubled by EPA's addition of this new requirement because it seems to undercut the whole purpose for the establishment of criteria -- the need for concrete and precise guidance for the conduct of sampling and cleanup. By adding an ALARA requirement as a supplement to the specific guidance, EPA seems to envision a regime in which the determination of the appropriate cleanup level must be negotiated and determined on a residence-by-residence or perhaps shovel-by-shovel basis. Such an approach is completely impractical.

Region 5 should endeavor to develop a full understanding of how the ALARA principle is applied. The NRC and the IDNS define ALARA in the following fashion:

> ALARA (Acronym for "as low as is reasonably achievable") means making every reasonable effort to maintain exposures to radiation as far below the dose limits in [part 20 of the NRC regulations] as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other society and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

10 C.F.R. § 20.1003 (1993); 32 Ill. Admin. Code § 332.1000(b). Any modification of standards on the basis of ALARA must thus be undertaken only after a careful assessment of actual risk and economic consequences.

In many circumstances ALARA does not require additional actions by licensees. For example, the NRC advises that compliance with ALARA can be satisfied by demonstrating that the expected doses are a fraction of the dose limit for members of the public (100 mrem/year). NRC, <u>Draft Regulatory Guide DG-8013: ALARA Levels for Effluents from Materials Facilities</u>, 5 (Oct. 1992) (hereinafter "<u>NRC Guide</u>") (Attached at Tab D). Thus, if the calculated dose from the 5 pCi/g cleanup standard achieves the goal, that is the end of the matter -- the ALARA principle is satisfied. (In such a calculation of dose, the NRC states that "[l]icensees need not assume worst case models when calculating dose but rather should make assumptions that will result in realistic estimates of actual dose received by the member of the public likely to receive the highest dose." NRC Guide, 5.)

ALARA also demands that any modification of the cleanup standards must be shown to be "reasonable." The NRC advises:

> A determination of reasonableness may be based on a qualitative analysis requiring the exercise of judgment and consideration of factors that may be difficult to quantify. These factors could include nonradiological social or environmental impacts, the availability and practicality of alternative technologies, and the potential for unnecessarily increasing occupational exposures.
>
> Alternatively, reasonableness may be based on a quantitative cost/benefit analysis. Preparation of an ALARA cost/benefit analysis requires the use of a dollar value per unit dose averted. The NRC staff is conducting a review and analysis of various methodological approaches to setting dollar values, and the staff recognizes that varying degrees of justification exist for a wide range of dollar values. However, the value of $1000 per person cSv (man-rem) has been acceptable to the NRC staff and may be used pending completion of that reassessment.

NRC Guide, at 6-7. We do not believe that the very slight further reduction in risk associated with more stringent cleanup than required by the radium-in-soil standard can be justified, particularly in light of the extraordinary cost that will be associated with the transport and disposal of each additional increment of soil removed from West Chicago.

The IDNS selection of a soil cleanup standard provides a demonstration of the application of the ALARA principle. The IDNS soil cleanup standard provides:

> [t]he concentration of total residual radium (radium 226 plus radium 228) in dry soil, after removal of soil or other materials that are being relocated, shall not exceed 5 picocuries per gram (5 pCi/g) above background concentrations of those radionuclides. Concentrations of radium in such residual soils shall be averaged over areas of 100 square meters and averaged over layers of 15 centimeter thickness. <u>The soil concentration of 5 pCi/g is deemed necessary to ensure that the licensee will</u> meet the requirements of 32 Ill. Adm. Code, sections 340.110(b) and 332.170(b) to <u>maintain doses to the public and releases to the general environment as low as is reasonably achievable (ALARA). A case by case demonstration that particular circumstances do not require cleanup to the above-stated goal will be considered</u>."

Condition 33 to Amendment No. 23 to License No. STA-583 (Sept. 1, 1994) (Attachment to Letter from R.A. Meserve to E. Deamer (Sept. 16, 1994)). IDNS thus has applied the ALARA principle as a guide to the selection of the specific numerical limit -- namely, to justify cleanup to the 5 pCi/g level -- and has not, as Region 5 proposes, applied ALARA as a vague and open-ended additional requirement. Moreover, IDNS has properly recognized that ALARA requires flexibility in the application of a numerical standard and, as such, the IDNS standard permits "[a] case by case demonstration that particular circumstances do not require cleanup [to 5 pCi/g levels]." <u>Id</u>. Although even IDNS's application of ALARA seems overly stringent, if Region 5 persists in considering an ALARA-based cleanup standard, the Agency should at least apply the ALARA principle in the same fashion as IDNS.

Conclusion

We urge Region 5 to revise the Engineering Evaluation/Cost Analysis to reflect the above comments.

Respectfully submitted,

Herbert Estreicher

Richard A. Meserve
Herbert Estreicher
COVINGTON & BURLING
1201 Pennsylvania Ave., N.W.
Washington, D.C. 20044
(202) 662-6000

W.O. Green, III
George B. Rice
Kerr-McGee CHEMICAL CORPORATION
123 Robert S. Kerr Avenue
Oklahoma City, OK 73125
(405) 270-3200

September 16, 1994

A

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
KERR-McGEE CHEMICAL CORPORATION	)	Docket No. 40-2061-SC
	)	ASLBP No. 84-502-01-SC
(Kress Creek Decontamination)	)	

TESTIMONY OF JOHN A. AUXIER, DOUGLAS B. CHAMBERS, AND EDWIN T. STILL ON THE RISKS ASSOCIATED WITH THE PRESENCE OF THORIUM-CONTAINING MATERIALS ALONG THE KRESS CREEK AREA AND WITH THEIR CLEANUP

March 31, 1986

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
KERR-McGEE CHEMICAL CORPORATION	)	Docket No. 40-2061-SC
	)	ASLBP No. 84-502-01-SC
(Kress Creek Decontamination)	)	

TESTIMONY OF JOHN A. AUXIER, DOUGLAS B. CHAMBERS, AND EDWIN T. STILL ON THE RISKS ASSOCIATED WITH THE PRESENCE OF THORIUM-CONTAINING MATERIALS ALONG THE KRESS CREEK AREA AND WITH THEIR CLEANUP

March 31, 1986

SUMMARY

This testimony sets out an evaluation of the risks that may arise from the presence of thorium-containing materials in and along Kress Creek and the West Branch of the DuPage River (hereinafter "Kress Creek" or "the Creek") and discusses the risks that would arise from the cleanup of the Creek to the levels specified in the Order to Show Cause. The principal conclusions of the testimony may be briefly summarized:

1. The major pathways that could result in radiation exposure to an individual in the vicinity of the Creek are: (a) exposure by way of external gamma radiation, (b) exposure from consuming produce from a garden located in thorium-containing soil, and (c) exposure from inhaling thoron daughters. A conservative analysis reveals that the typical dose from the materials to persons in the area would be only about 10 mrem/y or less. Even a hypothetical maximally exposed person could incur an incremental dose on the order of 85 mrem/y, and a dose of this magnitude is extremely unlikely.

2. The dose that might result from the materials does not warrant regulatory concern. The dose is below regulatory limits and constitutes only a fraction of the dose that results from natural background radiation. Moreover, the risk that could result from the materials is the same order of magnitude as the risk of death from driving a car for fifty miles; such risks are commonly considered to be completely insignificant and are normally accepted in everyday life without undue concern.

3. The NRC Staff's Order to Show Cause purports to apply certain radium-in-soil standards promulgated by the U.S. Environmental Protection Agency ("EPA"). The EPA standards are based on the risk to health that might result from constructing a home in soil that contains radium-226. The risk that could arise from construction of a home in soil containing radium-228 (the form of radium that is present along the Creek) is significantly less than that from construction in soil containing radium-226. Thus, it is scientifically incorrect to apply the EPA standards in the circumstances of Kress Creek.

4. The implementation of cleanup to meet the criteria set out in the Order to Show Cause will require extensive construction and transportation activities. The risk of a fatality from the implementation of remedial action is more than one chance in a hundred. In light of the comparatively slight risk that would result from maintaining the Creek in its present state, remedial action is unwarranted.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF EXHIBITS

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
KERR-McGEE CHEMICAL CORPORATION	)	Docket No. 40-2061-SC ASLBP No. 84-502-01-SC
(Kress Creek Decontamination)	)	

TESTIMONY OF JOHN A. AUXIER, DOUGLAS B. CHAMBERS, AND EDWIN T. STILL ON THE RISKS ASSOCIATED WITH THE PRESENCE OF THORIUM-CONTAINING MATERIALS ALONG THE KRESS CREEK AREA AND WITH THEIR CLEANUP

INTRODUCTION

On March 21, 1984, the NRC Staff issued an Order directing Kerr-McGee Chemical Corporation ("Kerr-McGee") to show cause why it should not be required to prepare and implement a remedial action plan to clean up certain thorium-containing materials in and along Kress Creek. Kerr-McGee responded to the Order by asserting, among other points, that remedial action is unwarranted in light both of the minimal health risks associated with the presence of the materials and of the comparative magnitude of the risks that would be associated with cleanup to the levels specified by the NRC Staff. This testimony sets forth an assessment of these risks.

This testimony is submitted by Dr. John A. Auxier, Dr. Douglas B. Chambers, and Dr. Edwin T. Still.[1] Dr. Auxier is the Director of Radiological Sciences for International Technology ("IT") Corporation. He has over thirty years of comprehensive professional experience in health physics and radiation dosimetry. He is the former President of Applied Science Laboratory, Inc., and the former director of the Industrial Safety & Applied Health Physics Division of the Oak Ridge National Laboratory. He has served on numerous special task forces and Advisory Committees concerned with national and international radiation issues, including the Task Group on Health Physics and Radiation Dosimetry of the President's Commission on the Accident at Three Mile Island, which he headed.

Dr. Chambers is a Vice President of SENES Consultants Limited. He has prepared numerous dose assessments for uranium mining activities and has conducted many other studies of environmental radioactivity and radiation protection. He is currently chairman of the Technical Committee on Environmental Radiation of the Canadian Standards Association (the Canadian analogue of the American National Standards Institute).

Dr. Still is Vice President and Director of the Environment and Health Management Division of the Kerr-McGee Corporation. He has also worked in assessing the health

---

1 Resumes of the panel are attached as Appendix A.

impacts from exposure to radiation throughout his professional career. Prior to his employment at Kerr-McGee, Dr. Still was Assistant to the Director (Biomedical Effects), Defense Nuclear Agency, a position that culminated a distinguished radiation research career as an officer in the U.S. Air Force.

Part I of this testimony sets out an analysis of the various pathways by which human exposure could result from the presence of thorium-containing materials along the Creek. This analysis enables an estimation of the typical radiation dose that might be incurred by a person in the area, as well as an estimate of the dose to a hypothetical maximally exposed person. Part II sets out an assessment of the significance of the dose that is estimated by the pathways analysis. Part III responds to certain questions that were posed by the Atomic Safety and Licensing Board Panel ("ASLBP") in this proceeding. Memorandum and Order (May 8, 1985). We respond to these questions in this testimony because they relate to the radiation environment and the risk in the Creek area. Finally, Part IV discusses the risks that would be incurred by the implementation of a remedial-action program to satisfy the criteria set out by the NRC Staff in the Order to Show Cause. Various appendices are provided to discuss in detail certain of the matters described in the text.

This testimony is founded chiefly on a survey of the radiation environment along the Creek that was undertaken by Oak Ridge Associated Universities. P.W. Frame, Comprehensive

Radiological Survey of Kress Creek, West Chicago Area, Illinois (1984) (hereinafter "ORAU Report").[1] In a few instances, as noted below, the data in the ORAU Report are supplemented by data provided by Kerr-McGee or others.

[1] The panel has undertaken no independent assessment of the validity of the ORAU data.

I. THE PATHWAYS FOR RADIOLOGICAL EXPOSURE ALONG KRESS CREEK

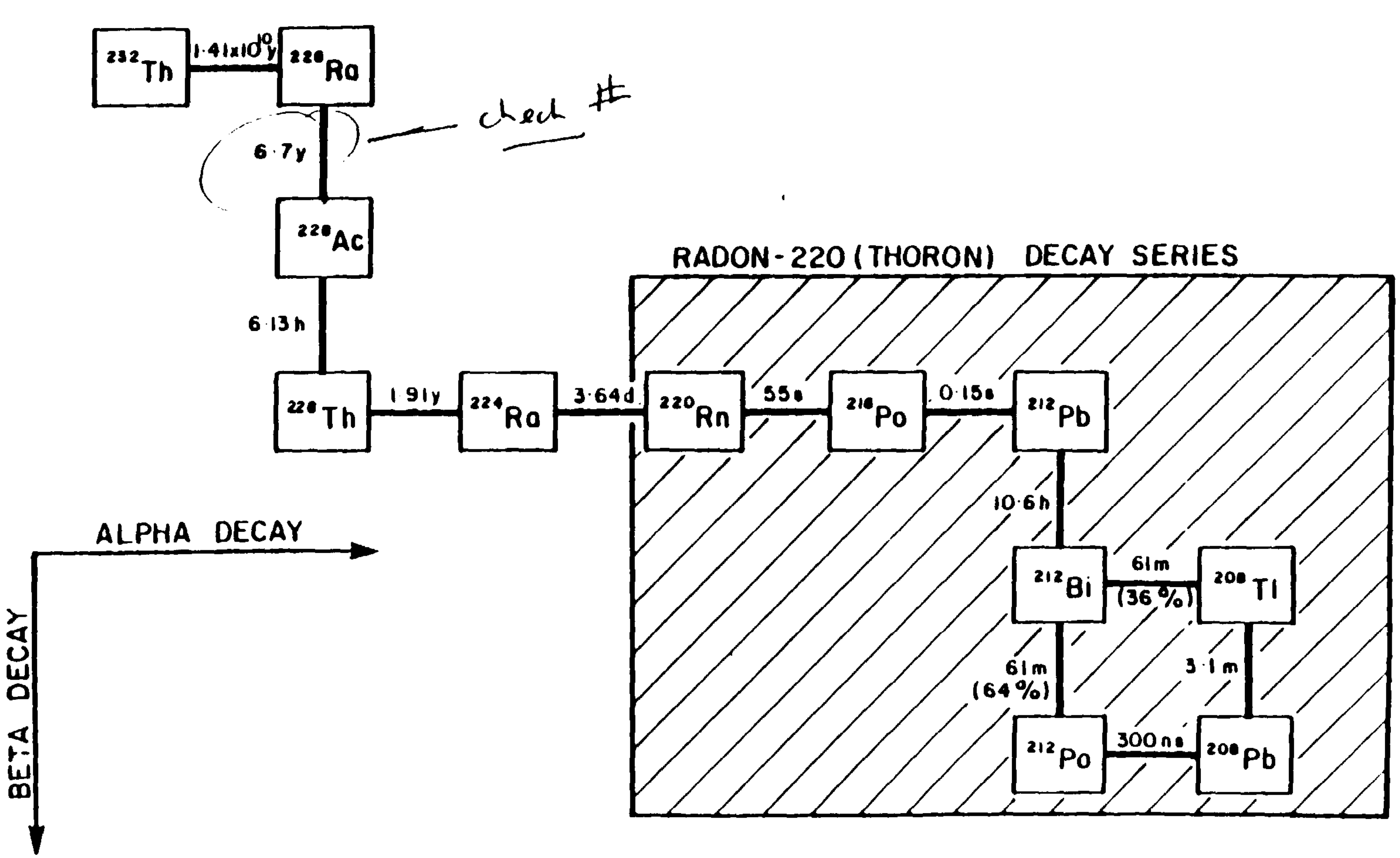
The assessment of the risk that could arise from the presence of thorium-containing materials[1] along Kress Creek was performed by first estimating the radiation dose that might be incurred by a person in the vicinity of the Creek. As is customary, the estimation of dose was performed by undertaking a detailed examination of the various pathways by which exposure of humans could occur. This chapter describes the pathways analysis.

Figure I-1 sets out the thorium-232 decay series. Thorium-232 decays through a chain involving a series of isotopes and ending in lead-208, which is a stable (non-radioactive) element. With one exception, all of the decay products are solids and thus will remain as constituents of the soil. Radon-220, which is usually referred to as "thoron" to distinguish it from radon-222 of the uranium decay series, is a gaseous isotope. Because thoron is inert, it can diffuse from the soil and be transported elsewhere through the atmosphere.

---

[1] The ORAU Report states that radionuclides of the uranium decay series, although present, are in quantities so low in comparison with thorium as to be "inconsequential." ORAU Report, 13.

Figure I-1 Thorium-232 decay series



Although no pathway was found that could result in a significant dose, there are several pathways that must be analyzed. First, gamma radiation is emitted as thorium and its progeny undergo radioactive decay in the soil. There is thus the possibility of gamma radiation exposure to humans who are present in the immediate vicinity of the materials. Second, thorium and its decay products might be taken up by vegetation that is grown in the thorium-containing soil. There thus could be exposure from consuming produce grown in a home garden located in the soil. Third, exposure could result from inhaling thoron and its daughters. Although various other pathways may exist -- for example, through the inhalation of thorium-containing dust or the direct ingestion of thorium-containing soil -- a scoping calculation has revealed that these other pathways are far less significant. The principal pathways are discussed in detail below.[1]

A. External Exposure

Thorium-containing materials are scattered along Kress Creek and people could be exposed to low levels of gamma radiation through casual use of the area for recreational or other purposes. The estimation of the potential dose from

---

[1] The ORAU Report (p. 13) states that "the primary mode for . . . exposure is external gamma radiation" and that "vegetable gardens . . . offer an additional, although probably not major, pathway for exposure." We concur, but have considered as well the exposure associated with other pathways.

external gamma radiation is determined from the gamma exposure rate and the predicted occupancy.

The ORAU Report provides exposure rates averaging from 28 uR/h at 1 m from the edge of the creek to 14 uR/h at 25 m from the edge of the Creek. ORAU Report, 7. In general terms, the exposure rates decrease with increasing distance from the edge of the water, with the highest exposure rates occurring in low-lying areas susceptible to flooding conditions. These measurements include the background exposures that exist naturally in the area. Because the background gamma exposure rates for the study area are approximately 8.6 uR/h,[1] the average gamma exposure rate from the thorium-containing materials alone ranges from about 19 uR/h to about 5 uR/h, depending on distance from the Creek. Overall, an average exposure rate above background of about 15 uR/h is conservative.

The land along the Creek consists of parkland, open field, and residential backyards. The most probable activites in the Creek-bank area include jogging and hiking, yard work, and backyard play. Because the data suggest that regions with markedly elevated exposure rates are small in areal extent and

---

[1] ORAU Report, 7. The ORAU estimate is consistent with the estimates of background provided by others. Myrick, et al. (1981) suggest 8.5 ± 4.1 uR/h as the U.S. average background external gamma exposure rate and 8.1 ± 2.5 uR/h as the average for Illinois.

are not correlated with each other,[1] an individual engaging in activities along the Creek would most likely encounter areas with varying exposure rates. The average gamma exposure rate is thus a reasonable and appropriate measure of the exposure rate that would actually be incurred by individuals in the Creek area.

The time period for exposure -- the occupancy factor -- must also be estimated. Although in good weather activities along the Creek might plausibly occur for several hours per day, such activities are likely to be severely reduced or even nonexistent during cold seasons or poor weather. The best estimates of occupancy time can be reliably determined only by observing the use of an area over an extended period. Fortunately, such data are available in West Chicago as a result of work by an NRC contractor. Frigerio, et al. studied the thorium residuals in the West Chicago area and determined occupancy factors by "observation of these areas over a period of two years, and by conversations with local residents, officials and police." (Frigerio, 1978, p. 9). The authors noted that occupancy is "inhibited simply by the relatively high fraction of inclement weather in this

---

[1] Data in the ORAU Report indicate that the areas with elevated soil thorium are both localized and variable along the banks of the Creek. As discussed in Appendix B, a gamma survey performed along the banks by Kerr-McGee confirms this observation.

area." (*Id*., p. 9). For "lawns and gardens of a sort experiencing some residential occupancy," they estimated a maximum occupancy time of 200 h/y. This is a reasonable estimate of occupancy to apply in calculating the gamma dose. ✗

Assuming an overall average exposure rate of 15 uR/h (0.015 mR/h) above background along the banks of the Creek and an exposure duration of 200 h/y, the annual gamma dose may be estimated:

$$0.015 \text{ mR/h} \times 200 \text{ h/y} = 3 \text{ mR/y}$$
$$= 3 \text{ mrem/y}$$

These calculations assume that for gamma radiation, 1 R is approximately equal to 1 rem (Cember, 1969).

It might be asserted that a greater dose could result if a person were to spend a significant amount of time during the course of the year in one of the localized areas with more elevated gamma intensities. In our view, any such scenario is improbable. As is discussed in detail in Appendix B, Kerr-McGee has undertaken a systematic gamma survey of the properties along the Creek. The survey reveals that only a small portion of the area along the Creek is characterized by markedly elevated gamma levels (*e.g.*, greater than 150 ur/h) and that the discrete regions along the Creek with such exposure rates are isolated from each other and have small areal extent.[1] In light of these facts, no one is likely to

---

[1] The maximum area for a region with a gamma intensity greater than 150 uR/h is 600 square feet.

have an extended day-to-day presence in the immediate vicinity of an elevated region. Nonetheless, we examine such a scenario to estimate a maximum exposure.

The ORAU Report indicates that the maximum exposure rate that was observed in a walk over surface scan was 210 uR/h at 1 meter. ORAU Report, 9, 39. If one conservatively assumes an exposure rate above background of 200 uR/h (0.20 mR/h) and an exposure duration of 200 h/y, the maximum annual gamma exposure may be estimated:

$$0.2 \text{ mR/h} \times 200 \text{ h/y} = 40 \text{ mR/y}$$
$$= 40 \text{ mrem/y}$$

It must be noted, however, that ORAU identified only one site along the Creek within an exposure rate over 200 uR/h at 1 meter and only three other sites were found to exceed 150 uR/h. ORAU Report, 39. Similarly, Kerr-McGee's survey has found that only a slight portion of the Creek had such elevated gamma readings. Thus, even if the few elevated regions were determined to be of concern, they would not justify the extensive cleanup envisioned by the Order to Show Cause.

In this connection it must also be observed that gamma intensities are significantly reduced by soil cover. For example, a 10 centimeter layer of soil will reduce the gamma exposure rate at one meter by 50% and a 30 centimeter cover will reduce it by 95%. As a result the gamma readings that are observed are likely caused by elevated concentrations of thorium in the surface layers of the soil. Moreover, water serves to shield the gamma radiation emitted by thorium-chain isotopes. A 30 centimeter thickness of water -- the average depth of the Creek (ORAU Report, 3) -- will serve to reduce the gamma exposure rate by about 90%. Thus, concern for the direct gamma exposure pathway cannot justify cleanup of the Creek bed or the buried (and shielded) thorium-containing materials.[1]

B. Dose from Home Garden Produce

Another potential exposure pathway is through the consumption of vegetables grown in home gardens located in thorium-containing soil. A walk over survey of the Creek has revealed only two gardens (Salamon Testimony). Moreover, even if such gardens were common in the area, no significant exposure would be likely to result.

The ingestion dose from a particular radionuclide by way of the ingestion pathway may be calculated using the following formula (NRC, 1980):

$$D_i = 0.5 \times U \times C_i \times DCF_i$$

---

[1] It might be postulated that materials in the Creek bed could later be deposited on the shore or that buried materials might somehow later be excavated. It is unlikely, however that such future disturbance of now shielded materials would appreciably affect gamma exposure. The volume of thorium contamination in the Creek bed is comparatively slight compared to the volume now on the banks (Auxier Testimony) and any disruption of either the materials in the Creek bed or the buried materials would likely serve to dilute and disperse them.

where

C_i = concentration of radionuclide i in vegetables [pCi/kg]

U = annual ingestion rate of garden vegetables [kg/y]

DCF_i = ingestion dose conversion factor for radionuclide i [mrem/pCi]

0.5 = fraction of initial radioactivity remaining after preparation for the table [dimensionless].

The concentration of radionuclide i in vegetables due to uptake from contaminated soil is given by the formula (NRC, 1980):

$$C_i = S_i \times B_i$$

where

S_i = soil concentration of radionuclide i [pCi/kg]

B_i = soil-to-plant transfer factor [dimensionless].

S_i is sometimes given as a surface concentration (pCi/m^3) divided by a soil density (kg/m^3).

The values of the parameters that enter these equations are shown in Table I-1. Based on the ORAU Report, a concentration of 20 pCi/g of total thorium (10 pCi/g of thorium-232) may be taken to be a representative value.[1] It

---

[1] The ORAU Report (p. 10) indicates that total thorium concentrations in soil decrease with increasing distance from the edge of Kress Creek as follows:

> At 1 m from the edge, average concentrations at the various depths were: 26.1 pCi/g, surface; 40.2 pCi/g, 15 cm; 38.9 pCi/g, 30 cm; 28.9 pCi/g, 60 cm; and, 18.7 pCi/g,

(footnote cont'd)

TABLE I-1

WHOLE BODY DOSE EQUIVALENT
FROM EATING HOME GARDEN VEGETABLES

	Thorium-232	Radium-228	Thorium-228	Total Dose** Equivalent (mrem/y)
soil concentration S_i (pCi/g)	10	10	10	
dose conversion factor (mrem/pCi)	2.7×10^{-3}	1.2×10^{-3}	3.8×10^{-4}	
Potatoes (30 kg/y)*				
concentration factor B_i	4.2×10^{-3}	3.0×10^{-3}	4.2×10^{-3}	
concentration C_i (pCi/kg)	42	30	42	
annual dose equivalent (mrem/y)	1.7	0.55	0.25	2.5
Other vegetables (23 kg/y)*				
concentration factor B_i	4.2×10^{-3}	1.4×10^{-2}	4.2×10^{-3}	
concentration C_i (pCi/kg)	42	140	42	
annual dose equivalent (mrem/y)	1.3	1.9	0.19	3.5
Total Annual Dose Equivalent** (mrem/y)	3.0	2.5	0.44	6

* Assumed intakes are 50% of total annual consumption as estimated by the NRC (1980).

** Actually 50 year committed dose equivalent. This dose will actually be received over the fifty years following intake.

is assumed that half the potatoes and other vegetables that are consumed in a year are derived from the affected home garden -- a conservative upper limit. The various other parameters for the analysis are taken from a similar analysis by the NRC (NRC, 1980, App. G) with the exception of the dose conversion factors. The dose conversion factors were obtained instead from the International Commission on Radiological Protection (ICRP No. 30, 1979); the ICRP factors are based on biokinetic models which are more recent than the models used by the NRC.[1] See also NCRP No. 84, 33 (1985).

The calculation set out in Table I-1 is only for the relatively long-lived radionuclides in the thorium-232 chain (Th-232, Ra-228, Th-228). It is appropriate to calculate the doses from only these specific radionuclides because the ICRP dose conversion factors (DCFs) implicitly account for the doses due to build-up of the shorter-lived radionuclides

---

(footnote cont'd)

> between 60 and 90 cm. These average values decrease by approximately 50% at 5 m from the edge of the creek, remain unchanged at 10 m, and at 25 m decrease to approximately 17% of the original concentration.

Because it is unlikely that a garden would be established on the edge of the Creek bank and because, in any event, a garden would extend away from the edge, a 20 pCi/g average is reasonable. (If a larger or smaller thorium concentration were used, the estimated value of whole body dose equivalent shown in Table I-1 would be affected proportionately.)

[1] The NRC recognized the validity of the ICRP factors in its recent proposed modification of its radiation-protection standards. 51 Fed. Reg. 1092, 1101 (Jan. 9, 1986).

within the body. It must also be noted that the ICRP DCFs are based on a whole body, 50-year committed dose; that is, the dose to the body following ingestion of a long-lived radionuclide, even though the dose is spread over fifty years, is assumed to occur in the year of intake. Thus, the calculated annual dose shown in Table I-1 would actually be received by an individual over the course of fifty years following intake of the radionuclides. This methodology has been used by the ICRP and many national organizations for years, although its acceptance in the United States is still under debate because it is considered by some to be unnecessarily conservative for some radionuclides.

As may be seen, the total whole body dose equivalent resulting from eating vegetables grown in a home garden with a soil level of 20 pCi/g total thorium is calculated to be about 6 mrem/y. Because it is likely that nearly all the people in the Kress Creek area would obtain far less than half of the vegetables they consume from home gardens, even this minimal exposure would be likely to affect only a few people.

It might be asserted that the garden could be placed in one of the regions containing concentrations of thorium in excess of the average. In order to provide an estimate of the maximum dose, it is necessary to determine the maximum concentration of thorium that could be found in a 10m-by-10m garden.[1] Such an estimate can be obtained by averaging the ORAU data over contiguous 1 meter, 5 meter, and 10 meter sampling points for the surface, 15 cm, and 30 cm depths (the likely depth of the garden). The highest such concentration reported by ORAU is about 200 meters downstream from ORAU's first sampling point along the east bank of Kress Creek.[2] ORAU Report, Table 5. Thus the maximum average thorium con- 55 centration over the assumed garden is about 110 pCi/g of total thorium. Even in the extremely unlikely event that a person were to establish a garden providing half of his annual consumption of vegetables in this very spot, the maximum resulting dose would be only about 33 mrem/y.

C. Inhalation of Thoron

Two scenarios for exposure through thoron emissions may be envisioned. First, one could postulate that a house could be built in contaminated soil, resulting in increased exposure to thoron and its daughters by the occupants. Second, thoron emitted by the thorium-containing materials along the Creek might be transported through the atmosphere to a receptor. Neither scenario results in meaningful exposures.

---

[1] If the plot were smaller, it would likely be incapable of satisfying fifty percent of the assumed annual vegetable consumption.

[2] Although there are isolated points with greater concentrations, the ORAU data and the Kerr-McGee survey suggest that there is likely to be significant variability in concentration over an area of the size of the assumed garden. As a result, an average measure is necessary.

1. Dose From Living in a Home Built on Thorium-Containing Soil.

As is discussed subsequently, the chief explanation offered by EPA to justify its radium-in-soil standard arises from the exposure that might arise if a home were built in soil that contains elevated levels of radium-226. The Staff purports to apply this standard in its Order to Show Cause. The postulated pathway is largely academic in the circumstances presented along Kress Creek for two reasons.

First, as shown in Exhibit A, most of the thorium-containing material identified in the ORAU Report lies in the Kress Creek flood plain, as defined by the U.S. Army Corps of Engineers.[1] (Dept. of the Army, 1975). This is hardly surprising since flooding is a likely mechanism to explain the distribution of the materials in the Creek area.[2] Moreover, Kress Creek and the West Branch of the DuPage River have a history of frequent flooding. For example, floods have been recorded in the area in 15 of the 35 years between 1940 and 1975.[3] Because of the prospect of flooding, it is implausible

---

[1] The Intermediate Regional Flood shown on Exhibit A is defined as a flood that has an average frequency of occurrence of once in 100 years.

[2] The one exception to the general rule is found in the vicinity of Gunness Lake. The thorium-containing materials along the Creek may have been redistributed when Gunness Lake was dredged.

[3] "Damaging floods" occurred in March 1948, April 1950, October 1954, July 1957, and August 1972. Other years in which there was flooding include 1942, 1947, 1949, 1951, 1953, 1959, 1961, 1962, 1966, and 1967. (Dept. of the Army, 1975, p. 9).

to believe that homes will be built in thorium-containing soil.

Second, even if a house were built in the flood plain, the resulting doses would be slight. The theory for predicting the indoor thoron and thoron daughter levels in homes is described in detail in Appendix C. For this analysis, it was assumed that a 10 m x 10 m house was surrounded by a 1 m thick layer of soil containing 20 pCi/g of total thorium (10 pCi/g of thorium-232). See supra p. 12, note 1. The analysis was undertaken for houses with various ventilation rates, ranging from a very "tight" home with 0.2 air changes per hour (ac/h) to an "open" house with 5 ac/h. A ventilation rate of 1 to 2 ac/h is probably typical for the area (EPRI, 1985). The other parameter values for the calculation are given in Table I-2 and the resultant doses for various ventilation rates are given in Table I-3. As may be seen, the ventilation rates have little effect on the build-up of thoron, but have a great effect on the build-up of thoron daughters.

The dose for a typical home (i.e., a home with an air exchange rate of 1-2 ac/h) built in soil containing 20 pCi/g of thorium would be less than 0.015 WLM/y, or 2 mrem/y.[1] If higher or lower soil concentrations of thorium-232 were

---

[1] The whole body dose equivalent per WLM for radon daughters is about 1 rem per WLM for occupational exposure (ICRP No. 32, 1981) and 0.5 rem per WLM for non-occupational exposure (NEA,

(footnote cont'd)

TABLE I-2

PARAMETER VALUES USED IN THE CALCULATION OF INDOOR DOSE

House floor area (m^2)	100
House volume (m^3)	200
Depth of contamination (m)	1
Emanating area (m^2)[a]	40
Thorium-232 soil concentration (pCi/g)	10
Thoron wall attenuation[b] (m^{-2})	0.004
Thoron emanation rate (pCi/m^2 s per pCi/g of thorium-232)[c]	77
Fraction of time spent in house	0.75

Notes

a - 1 m deep x 10 m per side x 4 sides.

b - Obtained by dividing the wall attenuation factor for radon of 0.3 (U.S. DOE, 1983) by 77 (see Part III).

c - Obtained by multiplying the radon emanation rate (a flux) of 1 pCi/m^2s per pCi/g of radium-226 (U.S. DOE, 1983) by 77 (see Part III) and by assuming that thorium-232 and radium-224 are in equilibrium.

TABLE I-3

WHOLE BODY DOSE EQUIVALENT FROM LIVING IN A HOUSE BUILT ON THORIUM-CONTAINING SOIL[1]

Ventilation Rate (ac/h)	Equilibrium Fraction [2]	Thoron (pCi/L)	Thoron Daughters (WL)[3]	Exposure (WLM/y)	Effective Dose (mrem/y)[4]
0.2	0.24	0.049	1.5×10^{-3}	0.06	9.0
0.5	0.11	0.049	7.0×10^{-4}	0.027	4.1
1	0.058	0.048	3.7×10^{-4}	0.015	2.2
2	0.030	0.047	1.8×10^{-4}	0.007	1.1
5	0.012	0.044	7.0×10^{-5}	0.0027	0.4

Notes

ac/h = air changes/hour

1 - Based on assumptions in Table I-2 and the theory outlined in Appendix C.

2 - From Krisiuk (1980).

3 - Assumes 7.5 pCi/L of thoron = 1 WL at 100% equilibrium (UNSCEAR, 1977; ICRP, 1981).

4 - Assumes 1 WLM (thoron daughters) = 150 mrem whole-body dose equivalent.

+ 2. 75% occupancy

1 d 1.5×10^{-3} WL $\times \frac{8760}{170} \times .75 \times 2.00$

assumed, the estimates for the whole body dose equivalent shown in Table I-3 would scale proportionately. Thus, in the unlikely event that a person were to build a typical home in the region of maximum thorium concentration (110 pCi/g), the hypothetical maximum whole body dose equivalent would be less than 11 mrem/y.

For comparison purposes, it is appropriate to note that the average annual exposure in the United States to radon daughters, which are three times more hazardous per WLM than thoron daughters, is about 0.2 WLM/y (NCRP, 1984b) -- an order of magnitude more than is calculated here for a typical home that might be built in the thorium-containing soil along the Creek. Moreover, the results set out in Table I-3 assume that the thoron daughters are not removed from the air by mechanisms such as plate-out (electrostatic attraction to walls and other surfaces) or dust deposition (attraction to airborne dust particles). Thus, the actual dose may in fact be far less than that which we have calculated.

2. Outside Air Transport of Thoron

It might be postulated that thoron emitted by the materials along Kress Creek could be transported through the

---

(footnote cont'd)

1983). (The different dose results chiefly from differences in breathing rates.) The ICRP (ICRP No. 32, 1981) has observed that the total effective dose per WLM from inhaled thoron is about one-third that of radon-222. Thus, the effective dose equivalent per WLM for thoron daughters is approximately 0.3 rem per WLM and 0.15 rem per WLM for occupational and non-occupational exposure, respectively.

outside atmosphere, with resulting exposure of the local population. The insignificance of this pathway is demonstrated by the actual measurements by EPA of ambient airborne radioactivity in West Chicago. (Jensen, et al. 1984). Although a station along Kress Creek was originally selected by EPA to obtain thoron-daughter information from the thorium-containing materials along the Creek, the authors concluded that the "[r]esults of the study did not show an appreciable effect" at the station. (Id., 1023) In short, thoron daughter levels measured with modern instrumentation in close proximity to thorium-bearing materials along Kress Creek were not affected by the presence of the thorium-bearing materials. The data thus show that the exposure from this pathway is inconsequential.

The insignificance of the scenario can also be inferred from the characteristics of the radioactive decay chain for thoron. Thoron has a 55 second half-life. Thus, as thoron is transported away from its source, the thoron level decreases rapidly with increasing travel time. The assumption that thoron can be transported significant distances away from the source and enter structures, followed by ingrowth of its daughters, is therefore invalid. Moreover, lead-212, which is a member of the thoron decay chain, has a relatively long half-life of about 10.6 h. This long half-life delays the ingrowth of subsequent daughters until the lead-212 has been transported great distances, with correspondingly large dilutions and hence low thoron working levels.

D. Summary

Using what we consider to be conservative assumptions, the likely annual incremental gamma dose associated with activities along Kress Creek would be about 3 mrem/y. The maximum annual gamma dose, which we believe is highly unlikely to be incurred, would be about 40 mrem/y, assuming reasonable occupancy times over the course of a year in an area with elevated gamma exposure rates. The maximum gamma dose could be sharply reduced by remedial actions that are far less extensive than those suggested by the Order to Show Cause.

upper [illegible]

A person deriving half his yearly consumption of vegetables from a garden in soils containing 20 pCi/g of total thorium -- the average along the Creek -- would receive a whole body dose equivalent of about 6 mrem/y. Although the dose would increase proportionately if the soil concentrations of thorium were higher, it would also be proportionately reduced if the vegetable consumption from the garden represented a smaller fraction of total annual consumption. We thus believe 6 mrem/y is a reasonable estimate for this pathway. But even if a person were to establish a 10m-by-10m garden in the region with the highest observed thorium concentrations and were to consume half his annual intake of vegetables from that garden, the dose from garden vegetables would be only about 33 mrem/y.

The inhalation pathway yields negligible doses. If a typical home were built in soil containing 20 pCi/g of total thorium over the top meter, the annual whole body dose equivalent to the inhabitants would be approximately 2 mrem/y. We are not aware of any home construction in thorium-containing soil in the Kress Creek area and believe that future construction in the floodplain is improbable. Nonetheless, even if a typical home were built in the region of the highest average thorium levels (110 pCi/g), the likely whole body dose equivalent would be on the order of 11 mrem/yr. Moreover, the impact of thorium-containing soils along the Creek on outdoor thoron levels is inconsequential, as shown by both theory and measurements.

In sum, a hypothetical maximally exposed individual -- a person who remains in the vicinity of an area of high gamma exposure rate over the course of a year, who consumes a significant portion of his vegetables from a garden in soil in the region of the highest observed thorium contamination, and who lives in a home constructed in soil in that region -- would receive a dose of only about 85 mrem/yr. But such a dose is highly unlikely. The likely incremental dose to a person engaging in activities along the Creek and consuming vegetables produced in its soil is on the order of 10 mrem/y or less.

II. THE SIGNIFICANCE OF THE DOSE FROM THORIUM-CONTAINING MATERIALS ALONG THE CREEK

The previous section sets out an estimate of the dose that might result from the presence of the thorium-containing materials along the Creek. The significance of this dose can be assessed in several ways.

First, the dose can be compared with appropriate regulatory limits. The existing NRC regulatory standards for protection against radiation authorize a licensee to release radiation to an unrestricted area, so long as any individual is not likely to receive a whole-body dose in excess of 500 mrem/y. 10 CFR § 20.105. This 500 mrem/y limit is preserved in NRC's proposed amendments to the standards, although the regulations also provide a "reference level" of 100 mrem/y as an action level for a licensee. 51 Fed. Reg. 1112-13, 1133 (Jan. 9, 1986). See also ICRP No. 26, ¶ 119 (1977) (100 mrem/y is acceptable for lifetime exposure). The maximum hypothetical dose for a person in the vicinity of Kress Creek is well within these guidelines.

Second, the exposures from Kress Creek may be placed in context by comparison with the doses stemming from existing levels of background (naturally occurring) radiation. The ORAU Report estimates the background gamma exposure rate along Kress Creek as 8.6 uR/h. Thus, a person residing in the area for a year would receive an external exposure of

$$8760 \text{ h/y} \times 8.6 \text{ uR/h} = 75 \text{ mR/y}$$
$$= 75 \text{ mrem/y}$$

 Perspective

A resident in the area is also exposed to naturally occurring radon daughters at a rate of about 0.2 WLM/y (NCRP No. 78, 1984, p. 165) or a whole-body dose equivalent of roughly 100 mrem/y. Finally, naturally occurring internal emitters contribute a dose of about 25 mrem/y (NCRP No. 45, 1975). Thus, natural sources of radiation provide a dose of about 200 mrem/y. The hypothetical maximally exposed individual along the Creek would receive an incremental dose of about a third of this value.

Third, the significance of the incremental radiation exposures resulting from the thorium-containing materials along Kress Creek may be assessed by estimating the risk resulting from the exposure. The ICRP has estimated that the risk of fatal cancer induction in persons exposed to ionizing radiation is approximately 1.25×10^{-4} per rem.[1] (ICRP No. 26, 1977, ¶ 60) The hypothetical maximally exposed individual would thus confront a risk that is about 1×10^{-5}. And, a typical individual along Kress Creek -- with an estimated incremental exposure of about 10 mrem/y or less -- would confront an annual fatal risk of about one in a million.

These risks may be placed in context by comparison with the risks from other ordinary human activities. Table II-1, based on the work of several researchers (Oser, 1978; Pochin,

---

[1] If impacts on the first two generations are included, the risk is estimated by ICRP at 1.65×10^{-4} per rem. The NRC has recently applied the ICRP risk estimates in its proposed new radiation-protection standards. 51 Fed. Reg. at 1102.

TABLE II-1

SELECTED ACTIVITIES WITH A RISK
OF DEATH OF ONE IN A MILLION

Activity	Cause
Travelling 50 miles by car	Accident
A pedestrian being hit by a motor vehicle during a nine-day period	Accident
Travelling 10 miles by bicycle	Accident
Living 2 months in an average stone or brick house	Cancer from the radioactivity of the building materials
Home accidents during three-day period	Falls, electrocution, etc.
Being struck by lightning during two-year period	Electrocution
Dying from air pollution during two-day period	Various causes
Dying in a flood or tornado during a two-year period	Various causes
Living 2 months with a cigarette smoker	Cancer, heart disease
Smoking 1-2 cigarettes	Cancer, heart disease
Drinking 0.6 ounces of beer per day for a year	Cancer (alcohol-related)
Drinking 2 ounces of milk per day for a year	Cancer (aflatoxin-related)
Living 20 minutes at the age of 60	All causes

1978; Wilson, 1979; Starr and Whipple, 1980; Crouch and Wilson, 1982) lists various activities that present one-in-a-million risks. For example, travelling 50 miles by car results in a one-in-a-million risk. As is apparent from the Table, such risks are commonly considered to be completely insignificant -- they are normally accepted in everyday life without any undue concern. As a result, the ICRP has observed that an acceptable level of risk for a member of the public is in the range from 10^{-5} to 10^{-6}. (ICRP No. 26, 1977, ¶ 118) And the NRC, in its recent proposed rulemaking to revise its radiation protection standards, has adopted the same conclusion. 51 Fed. Reg. at 1102.

We conclude that the risks derived from the presence of thorium-containing materials along the Creek are so slight that they do not warrant regulatory concern.

III. RESPONSE TO THE ASLBP QUESTIONS

The ASLBP has requested that the parties respond to several questions. Memorandum and Order (May 8, 1985). Kerr-McGee's responses are provided below.

A. Question 1

The ASLBP's first question seeks a comparison between radon and thoron. It reads as follows:

> For equal concentrations of radium-226 and radium-224 (pCi g^{-1} of soil), what are the relative consequences, in terms of the flux of daughter products at the ground surface (pCi m^{-2} s^{-1}), the concentration of radon and thoron in air (pCi L^{-1}) and the working levels produced in houses in the vicinity?

Our response discusses flux, the concentrations in outside air, and the concentrations and working levels in homes.

1. Flux

The flux may be readily calculated from the one-dimensional diffusion equation. For a layer of radium which is very thick compared to the distance through which thoron or radon can diffuse before decay, the flux (J) is given by the following equation (NRC, 1980, App. O):

$$J = R \rho E \sqrt{\frac{\lambda D}{P}}$$

R = radium-224 or radium-226 content [pCi/g]

ρ = bulk density [g/m^3]

E = emanating power (fraction of radon or thoron emanated to pore space)

λ = decay constant for thoron or radon $[s^{-1}]$.

P = porosity

D = bulk diffusion coefficient $[m^2/s]$.

Since both thoron and radon are chemically inert gases and have very nearly the same atomic weight, it is reasonable to assume that they have the same diffusion coefficient. Similarly, the other factors, with the exception of the decay constant, may be assumed to be the same for emissions from either radium-224 or radium-226. As a result, the relative fluxes are:

$$\frac{J_{thoron}}{J_{radon}} = \sqrt{\frac{\lambda_{thoron}}{\lambda_{radon}}} = 77$$

That is, the thoron flux at the ground surface is 77 times greater than the radon flux for equal specific activities of radium-224 and radium-226 in the soil. However, because thoron has a half-life that is orders of magnitude shorter than that of radon, its concentration will fall off more rapidly than radon in the atmosphere. Moreover, because thoron gas has a very short diffusion length (on the order of centimeters) compared to that of radon (on the order of meters),[1] any barrier placed between the source material

---

[1] The diffusion length is the distance over which the initial radon or thoron concentration falls off by a factor of 1/e. It may be calculated by the expression:

$$L = \sqrt{\frac{D}{\lambda P}}$$

Thus, thoron has a diffusion length that is 77 times shorter than that of radon and a barrier is 77 times more effective in reducing thoron than in reducing radon.

and the atmosphere will be far more effective in reducing thoron flux than it would be in reducing radon flux.

2. Concentrations in Outside Air

For normal situations the concentration of thoron in ambient air in the first few meters above the surface is roughly equal to that of radon (UNSCEAR, 1977). Because soil in the United States contains about 1 pCi/g radium-224 and radium-226, it appears that equal soil concentrations of radium-224 and radium-226 lead to approximately equal concentrations of thoron and radon in ambient air.[1] Limited data suggest that outdoor thoron working levels are likely to be smaller than outdoor radon working levels by a factor of about two to four (Jensen, 1984; Schery, 1985).

3. Concentration and Flux in Homes

The methodology for addressing the concentrations and working levels inside homes built on radium-containing soil is set out in Appendix C. The thoron concentrations and working levels in a home built in soil with 10 pCi/g of radium-224 are set out in Table I-3.[2] An identical calculation for a home in soil with 10 pCi/g of radium-226 yields

---

[1] Gesell (1983) has suggested that the mean radon concentration for normal areas of the contiguous United States lies in the range of 100 to 400 pCi m^{-3} and is probably about 250 pCi m^{-3}. Natural levels vary from area to area and depend on many factors including soil radium levels, soil moisture conditions and meterological parameters.

[2] If the soil contains 20 pCi/g of total thorium, it will contain 10pCi/g of thorium-232 and of each of its daughters, assuming equilibrium.

much higher radon concentrations and working levels because radon has a much longer half-life than thoron. The comparative results are set out in Table III-1. As may be seen, the indoor thoron daughter levels are predicted to be an order of magnitude lower than the corresponding radon daughter levels for a home built on soil containing equal specific activities of radium-226 and radium-224. For this reason, as well as the fact that exposure to thoron daughters is less hazardous than exposure to radon daughters, equivalent soil concentrations of radium-226 and radium-224 yield markedly different indoor exposure conditions.

The results of the calculations are supported by measurements of both radon and thoron daughter levels in 95 Canadian homes (Gunning and Scott, 1982). In this study the authors concluded that, although the thorium specific activity was at least equal to the uranium specific activity in the surface environment, thoron daughter levels in homes were generally insignificant compared to radon daughter levels.

B. Question 2

The ASLBP's second question reads as follows:

> Regardless of numerical standards, should occupancy factors be considered? Explain.

As is apparent from the analysis set out in Part I of this testimony, occupancy factors are an essential element in the estimation of the risk that is presented by thorium-containing materials along the creek. And, in our view, the estimate of risk must guide the evaluation of the need for cleanup.

TABLE III-1

COMPARISON OF THORON AND RADON EXPOSURE LEVELS
FOR HOMES BUILT ON SOIL CONTAINING 10 pCi/g
EACH OF Ra-224 and Ra-226

Ventilation Rate (ac/h)	Thoron and Daughters			Radon and Daughters		
	Equilibrium Fraction	Thoron (pCi/L)	Thoron-Dtrs (WL)	Equilibrium Fraction	Radon (pCi/L)	Radon-Dtrs (WL)
0.2	0.24	0.049	1.5 × 10-3	0.86	10.4	8.9 × 10-1
0.5	0.11	0.049	7.0 × 10-4	0.70	4.26	3.0 × 10-2
1.0	0.58	0.048	3.7 × 10-4	0.54	2.14	1.1 × 10-2
2.0	0.030	0.047	1.8 × 10-4	0.36	1.08	4.0 × 10-3
5.0	0.012	0.044	7.0 × 10-5	0.19	0.43	8.2 × 10-4

$$\bar{T} = \frac{1}{(\lambda_v + \lambda_r)}$$

$\frac{1.1 \times 10^{-2}}{3.7 \times 10^{-4}}$

$\frac{.5 \text{ rem}}{\text{WLM}}$ $\frac{.15 \text{ rem}}{\text{WLM}}$ $\frac{110}{5.7}$

C. Question 3

The ASLBP's third question reads as follows:

> The EPA "radium-in-soil" standards appear to be oriented toward control of possible health hazards in buildings that might be built on contaminated soil. Are such standards appropriate for soil within one (1) to five (5) meters of Kress Creek?

The Board is correct in noting that the "radium-in-soil" standards promulgated by the EPA were justified on the basis of reducing the risk to individuals living in homes which might be built in soil containing radium-226. (EPA, 1983, pp. 9-14 to -15, A.5-33, -35; EPA, 1982, pp. 107-111, 135). As discussed in response to question 1, however, indoor radon daughter levels from radium-226 in the soil are much higher than the thoron daughter levels from an equal specific activity of radium-224. Moreover, radon daughters pose a greater health risk per unit of concentration than thoron daughters. Thus, there is no scientific basis for applying to radon-224 the radium-in-soil standard that was derived for
radium
radium-226.

In addition, as discussed above, the areas with elevated concentrations of thorium occur for the most part within the flood plain of Kress Creek. <u>See</u> Exhibit A. It is therefore improbable that a house would be built in the thorium-containing soil in any event. Thus, even if the EPA radium-in-soil standards were scientifically valid in their application to radium-224 (which they are not), the pathway assumed by EPA is unlikely to arise in the specific circumstances found at Kress Creek.

D. Question 4

The ASLBP's fourth question reads as follows:

> The observations along Kress Creek by ORAU do not show the expected relationship between soil thorium concentrations and radiation levels one (1) meter above the ground surface. Is there an explanation for these data?

Figure 1 of the ASLBP Memorandum and Order shows a plot of observed gamma radiation levels versus soil thorium levels. Superimposed on the scatter plot is a straight line showing the "expected" relationship -- a straight line with a slope of 2.5 uR/h per pCi/g of thorium-232.[1] There is a marked deviation between the data and the predicted relationship.

There are several factors which can confound the problem of predicting an external gamma field from measured soil contamination levels. These include the geometric relationship between the source and the receptor, the effects of other gamma radiation emitters, and the spatial variability of thorium levels in soil. All of these may play a role in gamma radiation levels measured around Kress Creek.

---

[1] This relationship stems from a report by the National Council on Radiation Protection and Measurements (NCRP No. 45, 1975). In the NCRP Report, a value of 21.6 mrad/y per pCi/g of thorium-232 (plus daughters) is provided. Dividing this annual exposure rate by 8760 (the number of hours in a year) results in a value of 2.5 ur/h per pCi/g, essentially the slope of the straight line shown in the scatter plot in the ASLBP's memorandum.

We believe the geometric relationship between the source and the receptor has an important influence on measured gamma radiation levels.[1] Figure III-1 shows three idealized exposure situations. Figure III-1a represents a measurement at the center of an infinitely large plane source -- the situation to which the NCRP factor of 2.5 uR/h per pCi/g of thorium-232 applies. Under such conditions, the geometry factor has a value of 1.0.

Figure III-1b shows a receptor on the edge of an infinitely large plane source. In such a situation the receptor would be subject to gamma radiation at only one-half of the rate encountered while standing at the center of an infinite plane source. Under such conditions, the geometry factor is 0.5 and the predicted gamma radiation is then 1.25 uR/h per pCi/g of thorium-232.

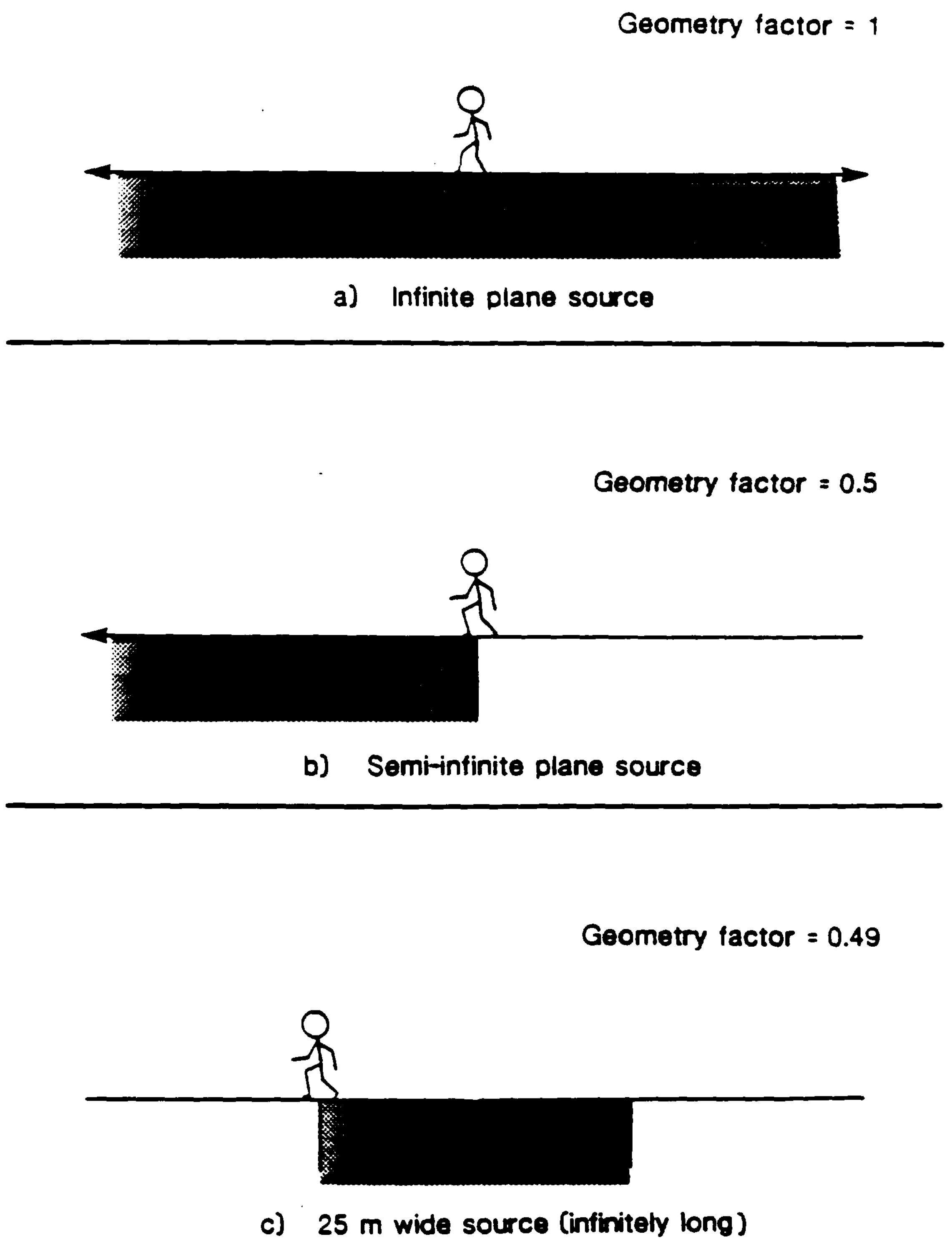
Figure III-1c shows a receptor at the edge of a uniform band that is 25 m wide and infinitely long. The geometry factor for this exposure situation is 0.49 (nearly half that for the infinite plane source) and the predicted gamma radiation is approximately 1.2 uR/h per pCi/g of thorium-232.

An analysis of the gamma intensities arising from various other configurations of thorium confirms the significance

---

[1] A review of procedures that can be used to calculate the effect of source-receptor geometry are set out in Chambers et al., 1981.

Figure III-1 Effect of source geometry on exposure



of the geometry factor. For example, if the receptor is at the center of one edge of a 10m-by-10m rectangle, the geometry factor is about 0.46. Similarly, the geometry factor for a circular source that is 4 meters in diameter is about 0.5 for a receptor at the center of the circle.

It is apparent that the geometry factor is important in understanding the gamma field in the vicinity of Kress Creek. The ORAU Report and the survey that was undertaken by Kerr-McGee show that the thorium-containing regions should not be seen as infinite plane sources. Rather, the thorium-containing material giving rise to the gamma field tends to be localized and variable. It is thus not surprising that the data do not conform to the relationship that is predicted between soil-concentration levels and radiation levels for an infinite plane source.

Figure III-2 is modelled after the scatter plot of measured exposure rate versus soil thorium concentrations presented in the ASLBP Memorandum and Order. In this figure the gamma exposure rate and soil thorium-232 levels were taken from Tables 2 and 5 of the ORAU Report.[1] Also shown on the

---

[1] Thorium-232 levels (total thorium divided by two) were used since this isotope provides the basis for the relationship of thorium levels to gamma exposure in NCRP No. 45. The thorium-232 levels shown on the figure are those for surface samples -- the samples collected from the 0 to 15 cm soil layer (ORAU Report, 6). (One outlying data point showing 92 uR/h at 23 pCi/g was removed from the analysis.) Due to the shielding effect of the overlying soil, the thorium-232 in deeper soil layers would contribute very little to the observed gamma levels.

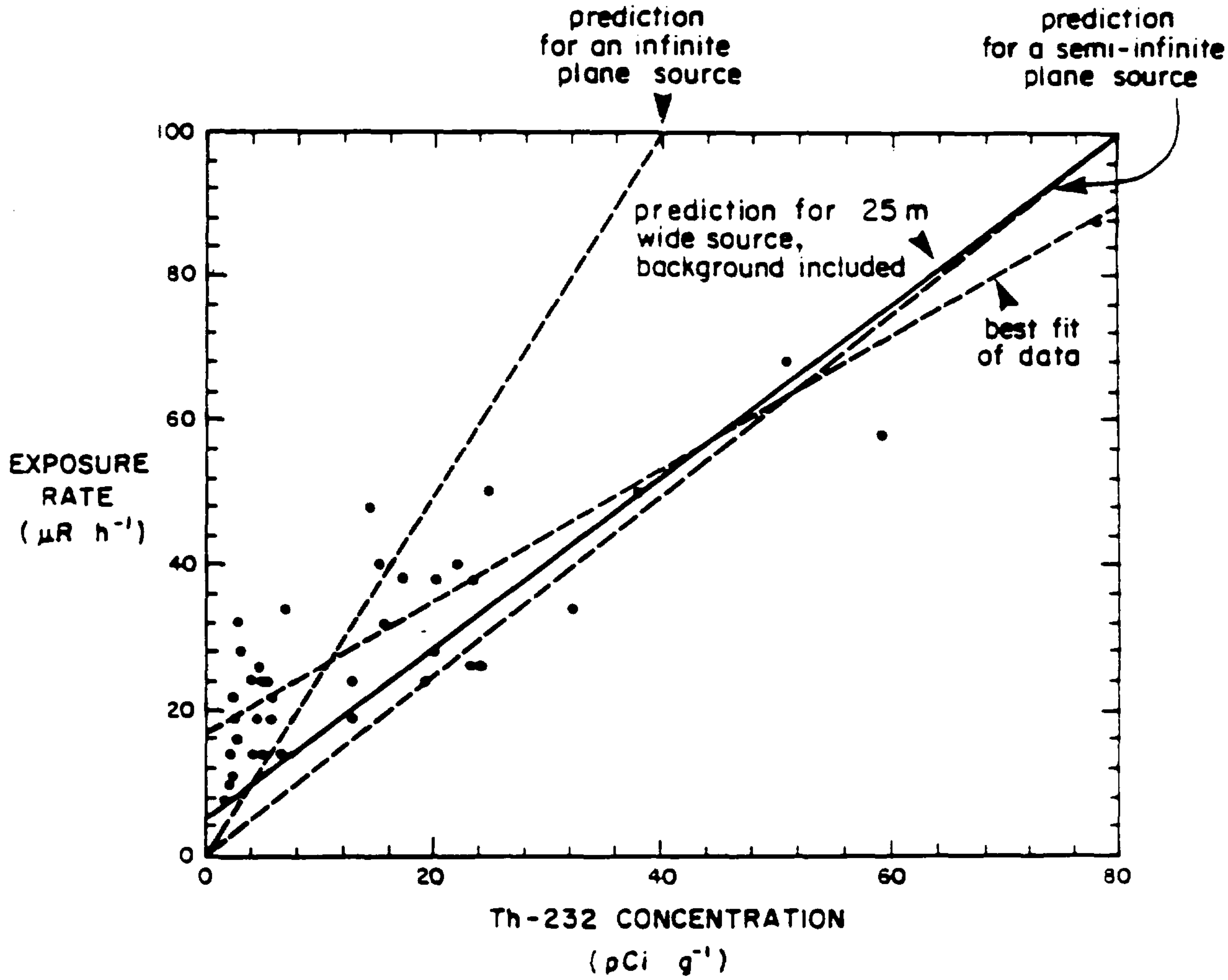


Figure III-2 External gamma exposure rate versus soil Thorium–232 levels

Notes: 1) thorium - 232 = $\frac{\text{total thorium}}{2}$

2) see text for discussion

figure is the best-fit line determined by a linear, least-squares regression technique. The slope is 0.92 ± 0.11 uR/h per pCi/g and the intercept on the dose rate axis is 16.7 ± 2.4 uR/h. (The errors quoted are standard errors calculated from the regression analysis.) A non-zero intercept is not surprising because terrestrial gamma radiation from other radionuclides in the soil, notably potassium-40 and the uranium-238 decay series, also contribute to background terrestrial radiation levels. Background gamma radiation levels in the study area average 8.6 uR/h.

Superimposed on the scatter plot are three theoretical lines of dose rate versus the level of thorium-232 in soil. The three theoretical lines are for a receptor standing in the middle of an infinite plane source, for a receptor standing at the edge of an infinite plane source, and for a receptor standing at the edge of a 25 m wide band of thorium-232. In this last case the theoretical line was predicted using the relation 1.18 uR/h per pCi/g of thorium-232, plus a background of 6 uR/h.[1] A line that includes adjustments to reflect the geometry of the source appears to conform to the measured data reasonably well.

---

[1] The background value was estimated assuming a normal background thorium-232 level of 1 pCi/g and the relation 2.5 uR/h per pCi/g thorium-232 -- that is, of the 8.6 uR/h of total background, about 6 uR/h is from sources other than thorium-232.

IV. THE RISK ASSOCIATED WITH REMEDIAL ACTIVITIES

Any remedial work undertaken in and along Kress Creek will involve both construction and transportation activities, and thus will pose risks to those carrying out the program. The risk can be estimated on the basis of manhours required for construction work and the truck mileage that is involved in hauling excavated material and clean fill. As will be seen, these risks are significant in comparison with the slight risks associated with the continued presence of the thorium-containing materials along the creek.

A. Construction

The U.S. Department of Labor's Bureau of Labor Statistics provides fatality data for various industries. Pertinent data for the construction industry for a recent five-year period are presented in Table IV-1, with the rates expressed as deaths per year per 100,000 workers and as deaths per million employee hours.[1]

Cleanup to the levels specified in the Order to Show Cause is estimated to require a total of about 56,000 man hours of various construction activities. Testimony of Thorsen, Taylor, and Denny. Thus, the risk of a construction fatality from the implementation of the cleanup program is

---

[1] The conversion was accomplished by setting one man-year equal to 2080 manhours.

TABLE IV-1

CONSTRUCTION INDUSTRY DEATH RATES

Year	No. of Fatalities Per Year	Annual Avg. Employment (1000's)	Deaths/100,000 Workers	Deaths/1,000,000 Employee Hours
1979	960	3138	30.6	0.147
1980	830	3103	26.7	0.129
1981	800	2982	26.8	0.129
1982	720	2894	24.9	0.120
1983	670	2916	23.0	0.111
Average	796	3007	26.4	0.127

Reference: U.S. Dept. of Labor, 1981, 1983, and 1985.

include driver | pedestrian

about 0.0073 (56,000 man hours x 0.13 deaths per 10^6 man hours) -- about 7 chances of a fatality in one thousand.

B. Transportation

The remedial program for Kress Creek will also require extensive transportation of materials, thorium-containing soils, and clean fill. Cleanup to the levels specified in the Order to Show Cause is estimated to involve over 17,000 truckloads, involving a total hauling mileage of over 136,000 miles. Testimony of Thorsen, Taylor, and Denny.

Accident rates for large trucks are available for the State of Illinois from the Illinois Department of Transportation (Illinois, 1986). For the period 1981-1984, the accident rate for such trucks averaged 4.62 fatalities per 100,000,000 miles travelled. An accident involving such a truck occurred at an average rate of 618.6 per 100,000,000 miles travelled.

The estimated 136,000 miles of heavy truck mileage for the remedial activities thus yields a fatality risk of 0.0063 -- about six chances in a thousand -- and an accident risk of 0.84.

C. Summary

The implementation of a cleanup program to achieve the levels of cleanup specified in the Order to Show Cause will pose a risk of a fatality of about 0.013 -- 0.007 from construction plus 0.006 from transportation -- or more than one chance in a hundred.[1] That is, there is more than one chance in a hundred that someone will die to satisfy the NRC Staff's proposed cleanup criteria. In light of the slight risk that would result from maintaining the Creek in its present state, the risk associated with cleanup to the levels specified in the Order to Show Cause is excessive.

[1] A scoping calculation of the radiological risk associated with cleanup was also performed. The radiological risk is far less than the construction or transportation risk.

APPENDIX A

John A. Auxier, Director
IT/Radiological Sciences Laboratory
Oak Ridge, Tennessee 37831

Education:

1972	Ph.D. in Nuclear Engineering - Georgia Institute of Technology, Atlanta, Georgia.
1952	M.S. in Physics, Vanderbilt University Nashville, Tennessee.
1951	B.S. in Physics, Berea College Berea, Kentucky.
1960	Certified by American Board of Health Physics

Professional Experience:

9/85 - Present	IT/Radiological Sciences Laboratory, Oak Ridge, Tennessee, Director.
9/83 - 9/85	Applied Science Laboratory, Inc., Oak Ridge, Tennessee, President.
1/83 - 9/83	Evaluation Research Corporation, Oak Ridge, TN, Chief Nuclear Scientist.
1977 - 12/82	Oak Ridge National Laboratory, Oak Ridge, TN, Director, Industrial Safety & Applied Health Physics Division.
1972 - 1977	Oak Ridge National Laboratory, Oak Ridge, TN, Director, Health Physics Division.
	Gave increased emphasis to needs of practicing health physicists. Strongly encouraged fundamental research in health physics related areas. Directed research in the investigation of pathways of exposure and biological effects of pollutants (both nuclear and non-nuclear) and radiation safety.
1962 - 1972	Oak Ridge National Laboratory, Oak Ridge, TN, Chief, Radiation Dosimetry Program.

1955 - 1962	Oak Ridge National Laboratory, Oak Ridge, TN, Health Physics Division. Conducted research in radiation physics and dosimetry; participated and ultimately directed successful efforts to obtain radiation doses for survivors of nuclear bombings of Hiroshima and Nagasaki, Japan.
1952 - 1955	University of Texas Coordinated and directed Health Physics Program. Subsequently appointed Chairman, Department of Physics and Engineering Radiobiological Laboratory.
1944 - 1947	U. S. Army Air Corps., Fighter Pilot.

Special Consultant Activities:

1976 - Present	Consultant to Radiation Effects Research Foundation, Japan.
1979	Head, Task Group on Health Physics and Radiation Dosimetry, President's Commission on the Accident at Three Mile Island.
1978 - 1980	Member of Advisory Committee to U. S. Department of Energy for Northern Marshall Islands. Member of Department of Energy/ Defense Nuclear Agency Inspection and Advisory Team for Clean-up of Enewetak Atoll.
1979 - Present	Member of Dose Assessment Steering Group, U. S. Department of Energy.
1981 - Present	Member of the Safety Advisory Board for Three Mile Island Unit 2.
1980 - Present	Member of National Academy of Sciences Panel on Hiroshima/Nagasaki Occupation Forces.
1981	Member of NAS Committee on Emergency Management.
1981 - Present	Member of Advisory Council, Institute of Nuclear Power Operations.

Professional Societies:

Health Physics Society, (President-elect, 1976; President, 1977; Managing Editor, Health Physics Journal, 1974-1977; Editor, Health Physics Journal, since its inception in 1958-1974; Chairman, Health Physics Society Presidents' Emeritus Committee; Member, East Tennessee Chapter of the Health Physics Society). Chairman, Research Needs in Health Physics Committee, 1984.

American Strategic Defense Association;

Society of Risk Analysis;

National Academy of Sciences, (Sub-committee on Exposure at Tests of Nuclear Weapons, 1984.)

National Council on Radiation Protection and Measurements (Member, NCRP; NCRP Scientific Committee 63; NCRP Scientific Committee 57; NCRP Scientific Committee 28; NCRP Scientific Committee 34).

Special Awards

1962	Elda E. Anderson Award, Health Physics Society.
1962	National Preparedness Award, National Institute for Disaster Mobilization.
1980	Meritorious Public Service Medal, Defense Nuclear Agency.
1980	Delivered Eighth Wright H. Langham Memorial Lecture.
1984	Fellow, Health Physics Society.

Publications:

Author or co-author of over 75 open literature publications in instrumentation, dosimetry, natural radiation environment, radiation physics and radiobiology. Recipient of the two approved patents. Author of recently published book in ERDA Prestige Series entitled ICHIBAN: Radiation Dosimetry for the Survivors of the Bombings of Hiroshima and Nagasaki.

Publications

Auxier, J.A., G. Forman, 52 "Characteristics of X-Ray Excited Phosphorescence of Calcite," Physics, Rev. 87, 107A.

Auxier, J.A., P.N. Hensley, G.S. Hurst, W.A. Mills, March 1954, "Neutron Flux and Tissue Dose Studies with Fission Treshold Detector," ORNL-1671.

Auxier, J.A., C. Gentry, S.J. Kaplan, C.M. Rogers, November "1954 Some Effects of Cumulative Doses of X-Radiation Upon Learning and Retention in the Rhesus Monkey," A.F. School of Aviation Proj. 21-3501-0003, Report No. 11, MP-5511.

Auxier, J.A., W. Blakely, 1954, "A Constant Air Monitor for Alpha Emitting Isotopes," A.F. School of Aviation Med. Report No. 7, Project 21-3501-0003.

Auxier, J.A., June 1955, "A High Level Co-60 Irradiation Facility," A.F. School of Aviation Med. Report AF SAM 55-40.

Auxier, J.A., G.S. Hurst, June 25-27, 1956, "A Fast Neutron Insensitive Gamma Dosimeter," Proceedings of the Health Physics Society Annual Meeting. Ann Arbor, Michigan, p. 3-7.

Auxier, J.A., G.S. Hurst, R.E. Zedler, "Neutron Insensitive Beta Gamma Dosimeter." U.S. Patent No. 2,974,248.

Auxier, J.A., H.E. Gilbert, T.D. Strickler, "Fast Neutron Scattering from Thick Slabs." Nuclear Science and Engineering 3:11-18.

Auxier, J.A., G.S. Hurst, R.E. Zedler, 1958, "A Single Ion Detector for Measurement of Gamma-Ray Ionization in Health Physics 1:21-26.

Auxier, J.A., "Evaluation of Residential Structures for Shielding Against Fallout Radiation," Effects of Nuclear War Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the United States, pp. 148-151.

Auxier, J.A., J.O. Buchanan, C. Eisenhauer, H.E Menker, "Experimental Evaluation of the Radiation Protection Afforded by Residential Structures Against Distributed Sources." Atomic Energy Commission, CEX-58.1.

Auxier, J.A., R.D. Birkhoff, W.D. Dillow, "A Study of Cavity Ionization as a Function of Atomic Number by Use of a

Miniature Counter," ORNL-2724 (Master's Thesis - Vanderbilt).

Auxier, J.A., G.S. Hurst, "Application of Radiation Dosimetry Studies to the Evaluation of Environmental and Biological Consequences of Nuclear War." Biological and Environmental Effects of Nuclear War. Hearings Before the Special Committee on Atomic Energy, Congress of the United States, pp. 140-147.

Auxier, J.A., A.D. Callihan, G.S. Hurst, K.Z. Morgan, R.H. Ritchie, P.W. Reinhardt, F.W. Sanders, E.G. Wagner, "Dosimetric Investigation of the Radiation Accident," Vinca, Yugoslavia, IAEA TO/HS/22, pp.25-46.

Auxier, J.S., J.S. Cheka, F.W. Sanders, "A Simple Method of Minimizing the Energy Dependence of Pocket Ionization Chambers," Health Physics 2:308-309.

Auxier, J.A., T.D. Strickler, "Experimental Evaluation of the Radiation Protection Afforded by Typical Oak Ridge Homes Against Distributed Sources." Atomic Energy Commission, CEX-59.13.

Auxier, J.A., 1961, "Dosimetric Considerations in Criticality Exposure," Diagnosis and Treatment of Acute Radiation Injury, World Health Organization, Geneva, pp. 141-150.

Auxier, J.A., C.H. Bernard, W.T. Thornton, 1961, "Silver Metaphosphate Glass for Gamma-Ray Measurements in Co-Exisktent Neutron and Gamma-Radiation Fields," Selected Topics in Radiation Dosimetry, IAEA, Vienna, pp. 503-510.

Auxier, J.A., P.N. Hensley, F.W. Sanders, 1961, "A Device for Determining the Orientation of Persons Exposed to Neutron and/or Gamma-Radiation," Health Physics 5: 226-227.

Auxier, J.A., F.W. Sanders, W.S. Snyder, "Na^{24} Activation in the Dosimetry of Nuclear Accidents," Radioactivity in Man, G. R. Meneely, Editor, Charles C. Thomas, Publisher, Springfield, Illinois, pp. 201-211.

Bernard, C.H., W.T. Thornton, J.A. Auxier, "Silver Metaphosphate Glass for X-Ray Measurements in Coexistent Neutron and Gamma-Radiation Fields," Health Physics, 4: 236-243.

Auxier, J.A., A.D. Callihan, G.S. Hurst, K.Z. Morgan, P.W. Reinhardt, R.H. Ritchie, F.W. Sanders, E.B. Wagner, "Dosimetric Investigation of the Yugoslav Radiation Accident," Health Physics 5: 179-202.

Auxier, J.A., W.T. Thornton, "Some X-Ray and Fast Neutron Response Characteristics of Silver Metaphosphate Glass Dosimeters." ORNL-2912 (Master's Thesis - Vanderbilt).

Auxier, J.A., J.S. Cheka, F.W. Sanders, March 1961, "Attenuation of Weapons Radiation - Application to Japanese Houses - Operation Hardtack, Phase II, Program 39, Projects 39.1, 39.2," WT-1725.

Auxier, J.A., J.S. Cheka, F.F. Haywood, F.W. Sanders, J.H. Thorngate "Technical Concept - Operation BREN." Atomic Energy Commission, CEX-62.01.

Auxier, J.A., A.D. Callihan, G.S. Hurst, K.Z. Morgan, P.W. Reinhardt, R.H. Ritchie, F.W. Sanders, E.B. Wagner, "Dosimetry," The Vinca Dosimetry Experiment, IAEA Technical Report 6, pp. 25-43.

Auxier, J.A., F.W. Sanders, "Neutron Activation of Sodium in Anthropomorphous Phantoms," Health Physics 8: 371-379.

Auxier, J.A., "Dosimetry and Exposures in Nuclear Accidents," Nuclear Safety, 4: 111-112.

Auxier, J.A., L.W. Gilley, F.F. Haywood, "General Correlative Studies, Operation BREN," Atomic Energy Commission, CEX-62.03.

Auxier, J.A., "Ichiban: The Dosimetry Program for Nuclear Bomb Survivors of Hiroshima and Nagasaki - A Status Report as of April 1, 1964," Atomic Energy Commission, CEX-64.3.

Auxier, J.A., F.F. Haywood, E.T. Loy, "An Experimental Investigation of the Spatial Distribution of Dose in an Air-Over-Ground Geometry," Atomic Energy Commission, CEX-62.14.

Auxier, J.A., G.A. Andrews, C.C. Lushbaugh, "The Importance of Dosimetry to the Medical Management of Persons Accidentally Exposed to High Levels of Radiation," Personnel Dosimetry for Radiation Accidents, IAEA, Vienna, pp. 3-16.

Auxier, J.A., 1965, "The Health Physics Research Reactor," Health Physics, 11: 89-93.

Auxier, J.A., "Nuclear Accident at Wood River Junction," Nuclear Safety, 6: 298-301.

Auxier, J.A., F.F. Haywood, "Technical Concept-Operation HENRE," Atomic Energy Commission, CEX-65.02.

Auxier, J.A., F.F. Haywood, T.G. Provenzano, "Operation Plan-Operation HENRE," Atomic Energy Commission, CEX-65.03.

Auxier, J.A., "Ichiban: The Dosimetry Program for Nuclear Bomb Survivors of Hiroshima and Nagasaki," Proceedings of the Symposium on Protective Structures for Civilian Populations. NAS-NRC, Washington, pp. 121-126.

Auxier, J.A., J.S. Cheka, F.F. Haywood, T.D. Jones, J.H. Thorngate 1966, "Free-Field Radiation-Dose Distributions from the Hiroshima and Nagasaki Bombings," Health Physics 12: 425-429.

Auxier, J.A., R.T. Boughner, M.D. Brown, T.D. Jones, W.D. Snyder, "Distribution of Dose and Dose Equivalent in an Anthropomorphic Phantom Resulting from Broad-Beam Sources of Monoenergetic Neutrons," Transactions of American Nuclear Society 9: 357.

Auxier, J.A., R.T. Boughner, M.D. Brown, T.D. Jones, W.S. Snyder, November 1966, "Distribution of Dose and Dose Equivalent in an Anthropomorphic Phantom Resulting from Broad-Beam Sources of Monoenergetic Neutrons," Proceedings of Conference on Radiation Transport and Biological Effects, CONF-661125, pp. 25-45.

Auxier, J.A., "Dosimetry and Exposures in Nuclear Accidents," Nuclear Safety 8: 382-385.

Auxier, J.A., 1967, "Multilaboratory Intercomparisons of Neutron Dosimetry Systems," Neutron Monitoring, IAEA, Vienna, pp. 625-630.

Auxier, J.A., "Physical Problems of Dosimetry of Neutrons and Protons. Accidental Irradiation at Place of Work," EURATOM, S.A. Vaillant-Carmannge, Liege, Belgium, pp. 181-194.

Auxier, J.A., "Special Methods in Radiation Dosimetry," Principles of Radiation Dosimetry, K.Z. Morgan and J.E. Turner, Editors, John Wiley and Sons, Inc., New York, Chapter 7, pp. 215-241.

Auxier, J.A., F.F. Haywood, S. Helf, J.H. Thorngate, "Energy and Angular Distribution of Neutrons and Gamma Rays - Operation BREN," Atomic Energy Commission, CEX-62.12.

Auxier, J.A., Proceedings: Long-Range Biomedical and Psychosocial Effects of Nuclear War, Volume 1, First Interdisciplinary Conference, Defense Nuclear Agency, DASIAC Special Report 67.

Auxier, J.A., 1967, "Radiation Propagation and Shielding Experiments at the BREN Tower," Trans. American Nuclear Society 10: 726.

Auxier, J.A., K. Becker, E.M. Robinson (Editors), September 23-26, 1968, Proceedings of the Second International Conference on Luminescence Dosimetry, Gatlinburg, Tennessee, CONF-680920, 1021 pages.

Auxier, J.A., M.D. Brown, 1966, "Neutron Cross-Sections and Reaction Products for H, C, N, and O for the Energy Range from Thermal to 15 MeV," Proceedings of the First International Congress of Radiation Protection, Pergamon Press, New York, Volume 2, pp. 853-858.

Auxier, J.A., T.D. Jones, W.S. Snyder, "Neutron Interactions and Penetration in Tissue," Radiation Dosimetry, F.H. Attix and W.C. Roesch, Editors, Academic Press, New York, Chapter 6, pp. 275-316.

Auxier, J.A. T.D. Jones, D.R. Johnson, J.W. Poston, September 5-10, 1966, "Dose Distribution Functions for Neutrons and Gamma Rays in Anthropomorphous and Radiological Phantoms," Proceedings of the First International Congress of Radiation Protection, Rome, Italy, Pergamon Press, Volume 2, pp. 1461-1467.

Auxier, J.A., Thorngate, J.H., "Fast Neutron Spectrometry for Radioprotection," Colloque d'Electronique Nucleaire et Radioprotection, Tome 1, University of Toulouse, Volume 1 of 4, (27 pp.).

Auxier, J.A., 1969, "Kerma Versus First Collision Dose: The Other Side of the Controversy," Health Physics 11: 342-343.

Auxier, J.A., K. Becker, "Progress in Luminescence Dosimetry," Science 164: 974-978.

Auxier, J.A., "Multi-Laboratory Intercomparisons and Standardizations: Nuclear Accident Dosimetry Systems," Nuclear Accident Dosimetry Systems, IAEA, Vienna, IAEA-PL-329/13, pp. 153-164.

Auxier, J.A., H.H. Hubbell, Jr., T.D. Jones, November 11-14, 1969, "Review of Depth-Dose Calculation and Experimentation," Proceedings of the Symposium on Neutrons in Radiobiology, Oak Ridge, Tenn., CONF-691106, pp. 73-94.

Auxier, J.A., K. Fukushima, S. Fujita, T. Ishimaru, S. Jablon, November 11-14, 1969, "REB of Neutrons in Japanese Survivors," Proceedings of the Symposium on Neutrons in Radiobiology, Oak Ridge, Tenn., CONF-691106, pp. 547-579.

Auxier, J.A., D.G. Brown, D.R. Davy, W.D. Gibbs, W.A. Gramly, H.D. Hodges, D.R. Johnson, J.W. Poston, "'Total' and 'Exchangeable' Sodium Studies in Swine and Sheep Using Activation Analysis and Isotopic Dilution," Health Physics, 18: 729-731.

Auxier, J.A., "The Outcry Over Exposure Guidelines," Nuclear Safety 2: 456-460.

Auxier, J.A., "Review of Personnel Dosimetry Systems for External Radiation Exposure, IAEA Technical Report No. 109," Health Physics 21: 613.

Auxier, J.A., B.G. Auxier, 1971, "Review of the Story of Radioactivity," Health Physics 21: 126-138.

Brown, D.G., D.F. Johnson, J.A. Auxier, 1971, "Unilateral and Bilateral Exposure of Swine to Fission Neutrons," Health Physics 21: 537-545.

Auxier, J.A., F.F. Haywood, "Unusual and Unexpected Radiation Sources," Safety Newsletter of the National Safety Council (March).

Auxier, J.A., T.D. Jones, "Neutron Dose, Dose Equivalent, and Linear Energy Transfer from 252-Cf Sources," Health Physics 20: 352-358.

Auxier, J.A., T.D. Jones, W.S. Snyder, "Absorbed Dose, Dose Equivalent, and LET Distributions in Cylindrical Phantoms Irradiated by a Collimated Beam of Monoenergetic Neutrons," Health Physics 21: 252-272.

Auxier, J.A., J.H. Thorngate, "Advances in Dosimetric Instrumentation, American Nuclear Society Transactions, 14: 408-409.

Auxier, J.A., Z.G. Burson, R.L. French, F.F. Haywood, L.G. Mooney, E..A. Straker, "Nuclear Weapons Free-Field Environment Recommended for Initial Radiation Shielding Calculators," ORNL-TM-3396.

Auxier, J.A., T.D. Jones, "Local Dose from Neutron Produced Recoil Ions in the Region of a Therapeutic 252-Cf Needle," Radiology 104: 187-189.

Auxier, J.A., J.E. Turner, "Symposium on Radiation Standards and Regulations," Health Physics 23: 445-446.

Auxier, J.A., "Concluding Summary," Neutron Monitoring for Radiation Purposes, IAEA, Vienna, pp. 495-498.

Auxier, J.A., "Developments in Neutron Dosimetry for Radiation Protection," Neutron Monitoring for Radiation Protection Purposes), IAEA, Vienna, IAEA-SM-167/26, Volume 1, pp. 3-12.

Auxier, J.A., R.O. Chester (Editors), 1972, "Report of the Clinch Valley Study, May 15-June 2, 1972." ORNL-4835.

Auxier, J.A., D.J. Christian, T.D. Jones, G.D. Kerr, P.T. Perdue, W.H. Shinpaugh, J.H. Thorngate, "Contribution of Natural Terrestrial Sources to the Total Radiation Dose to Man." ORNL-TM-4323 (Ph.D. Thesis - Georgia Tech.).

Auxier, J.A., T.D. Jones, W.S. Snyder, G.G. Warner, "Dose to Standard Reference Man from External Sources of Monoenergetic Photons," Health Physics 24: 241-255.

Auxier, J.A., D.J. Christian, G.D. Kerr, W.H. Shinpaugh, "Preliminary Studies of the Effects of Sealants on Radon Emanation from Concrete," Health Physics 27: 389-391.

Auxier, J.A., P.T. Perdue, W.H. Shinpaugh, J.H. Thorngate, Determination of Radon in Air," U.S. Patent No. 3,805,070.

Auxier, J.A., P.T. Perdue, W.H. Shinpaugh, J.H. Thorngate, "A Convenient Counter for Measuring Alpha Activity of Smear and Air Samples," Health Physics 26: 114-116.

Auxier, J.A., J.S. Cheka, T.D. Jones, G.D. Kerr, "In Vivo Dose Estimates for A-Bomb Survivors Shielded by Typical Japanese Houses," Health Physics 28: 367-381.

Auxier, J.A., 1976, "Respiratory Exposure in Buildings Due to Radon Progeny," Health Physics 31: 119-125.

Auxier, J.A., "Physical Dose Estimates for A-bomb Survivors - Studies at Oak Ridge, U.S.A.," Journal of Radiation Research 16, Supplement: 1-11.

Auxier, J.A., 1976, "Studies Directed Toward the Spatial Resolution of the Distribution of Plutonium in Bone," Health Effects of Plutonium and Radium, Webster, S.S. Jee (Ed.), The J.W. Press, Salt Lake City.

Auxier, J.A., 1976 Ichiban: Radiation Dosimetry for the Survivors of the Bombings of Hiroshima and Nagasaki, ERDA Prestige Series.

Auxier, J.A., W.F. Ohnesorge, June 1980, "Gamma Exposure Rates Due to Neutron Activation of Soil: Site of Hood Detonation, Operation Plumbbob," Oak Ridge National Laboratory, ORNL/TM-7406.

Auxier,J.A., 1977, "Need for Improved Standards in Neutron Personnel Dosimetry," National Bureau of Standards Special Publication 493, Proceedings of the International Specialists Symposium on Neutron Standards and Applications, held at the National Bureau of Standards, Gaithersburg, MD, March 28-31, 1977.

Auxier, J.A., 1977, "Radiation Safety," Twenty-Fourth National Conference on Campus Safety, Monograph No. 39, Safety Monographs for Schools and Colleges, University of Hawaii at Manoa, Honolulu, Hawaii, June 9-16, 2977, pp. 58-60.

Auxier, J.A., 1977, "The regulatory pendulum, or, a matter of common sense...," American Industrial Hygiene Association Journal (38), 12/77.

Auxier, J.A., 1977, "Brief Synopsis of Symposium," IAEA International Symposium on National and International Standardization in Radiation Dosimetry, Atlanta, GA, December 5-9, 1977.

Eichholz, G.G., J.W. Poston, M.F. Fair, J.A. Auxier, May 1980, "Cost-Benefit Effects of Conversion to SI Units in Health Physics," Oak Ridge National Laboratory, NUREG/CR-1419; ORNL/NUREG-68.

Auxier, J.A., C.D. Berger, C.M. Eisenhauer, T.F. Gesell, A.R. Jones, M.E. Masterson, October 1, 1979, "Report of the Task Group on Health Physics and Dosimetry," President's Commission on the Accident at Three Mile Island.

Jones, T.D., D.G. Jacobs, J.A. Auxier, G.D. Kerr, 1979, "Risk of Cancer Based on Promotion from Cytotoxicity," Proceedings of a Conference on Neutrons from Electron Medical Accelerators (H.T. Heaton, II and R. Jones, Eds.) NBS Special Publication 554.

Auxier, J.A., 1978, "A Brief Synopsis of the Symposium," National and International Standardization of Radiation Dosimetry, Volume II, IAEA, Vienna.

Auxier, J.A., K.Z. Morgan, 1983, "Radiation, Ionising: Detectors and Portable Survey Instruments," Encyclopedia of Occupational Health and Safety, Volume II, ILO, Geneva, 1983.

Auxier, J.A., H.W. Dickson, 1983, "Guest Editorial: Concern Over Recent Use of the ALARA Philosophy," Health Physics 44: 595-600.

POSITION

Vice President
Director of Nuclear Studies

EDUCATION

B.Sc. (Honours), Physics, 1968, University of Waterloo (University of Waterloo Tuition Scholarship)
Ph.D., Physics, 1973, McMaster University (National Research Council Science Scholarship)
Two Sessions at the Advanced School for Statistical Mechanics and Thermodynamics, University of Texas, Austin, 1970 and 1971
Air Pollution Diffusion, U.S. EPA, Research Triangle Park, 1974
Annual Health Physics Course, Chalk River Nuclear Laboratories, 1974
Observations on Human Populations, School of Hygiene, University of Toronto, 1979

PROFESSIONAL AFFILIATIONS

American Nuclear Society
American Physical Society
Canadian Standards Association, Member of Technical Committee on Environmental Radiation Protection (1978 to present)
Canadian Radiation Protection Association
Health Physics Society
Institute of Electrical and Electronic Engineers
New York Academy of Sciences
Ontario Air Pollution Control Association

EXPERIENCE

1980-date SENES Consultants Limited. Vice President and Director of Nuclear Studies with corporate responsibility for studies of environmental radioactivity and radiation protection. Also provides technical assistance to atmospheric dispersion studies and air quality analyses.

Senior health physics advisor for studies pertaining to worker radiation protection. Such studies have involved dose assessment and the development of health and safety practices for uranium mine workers, ALARA optimization of underground uranium mining, the assessment of co-carcinogens in the uranium mine work environment, dose reconstruction for epidemiological studies of persons exposed to elevated radon daughter concentrations, and evaluation of scientific basis for uranium miner regulations.

Senior scientist for several studies that utilized environmental pathways analysis and other modelling techniques to investigate the release, distribution, and effect of radionuclides in the environment.

Douglas B. Chambers

Pathways analysis has been applied to the decommissioning of uranium mines and the establishment of derived release limits for both an existing and future uranium refinery. Manager of a study which modelled the behaviour of carbon-14 in the biosphere.

Directed the assessment of radiological aspects associated with the decommissioning of uranium mining operations at properties in northern Saskatchewan and provided similar advice to a property in Ontario.

Project manager for several low level radioactive waste management studies including the evaluation of specific waste management sites and development of disposal concepts, application of pathways models to assist in site investigations, reviews of the current status and legislation of LLRW management in North America, preparation of LLRW inventories in Canada.

Directed and provided technical input to air dispersion modelling of accidental chemical releases (including dense gases); numerical air quality modelling for complex terrain, calibration/verification studies, and development of long-range transport models.

1973-1980 James F. MacLaren Limited. General Manager, Nuclear Projects Division from 1977 to 1980. Responsible for the development of the firm's capabilities in the environmental radioactivity and radiation protection areas.

Project Manager in the Air Environment Division from 1973 to 1977. Responsible for projects in environmental radioactivity, air pollution control, and environmental noise.

Environmental advisor (air environment and/or radioactivity) on several environmental impact assessments. Assessments have been undertaken for the expansion of an existing uranium mining operation; multi-disciplinary studies to select a site for a new uranium refinery in Ontario; a site evalution for a uranium hexafluoride conversion plant; proposed uranium mining operations at several locations across Canada.

Radioactivity specialist on studies of public and worker health impacts at several proposed uranium mining operations; for the handling of slag at a phosphorus reduction operation; a review of industrial hygiene practices at Canadian uranium mines and mills; and radiation protection in the design of a nuclear fuel fabrication facility.

Specialist advisor on the development, implementation and interpretation of results from air quality and meteorological surveys at several types of industrial projects at locations across the country. Such studies have often included the development and use of atmospheric dispersion models for evaluating environmental effects.

Provided expert testimony at public meetings, hearings and inquiries that have addressed uranium mine operation and expansion, radioactive material clean-up programs, and atmospheric dispersion.

Involved in the assessment of the impacts of noise from a variety of projects including an ethylene plant, a petroleum coker, an airport, a polyethylene plant, and two coal mines. Also assisted in the development of noise exposure criteria for a large overseas industrial complex and adjoining city and the application of models for predicting environmental noise levels.

Assisted in the preparation of national inventories for mercury, lead, beryllium and asbestos as part of a sources and atmospheric emissions program.

1968-1973 McMaster University. Post-graduate studies related to research in thermodynamics of irreversible processes.

TECHNICAL PAPERS AND PRESENTATIONS

"A Pilot-Scale Optimization Analysis of Underground Uranium Mining in Elliot Lake" to be presented at the International Conference on Occupational Radiation Safety in Mining", Toronto, October 1984 (with L.M. Lowe, J.L. Chakravatti, K. Black).

"Design for Beta Radiation Protection in Mining and Milling of High Grade Uranium Ore." to be presented at the International Conference on Occupational Radiation Safety in Mining", Toronto, October 1984 (with J. Mernagh)

"Potential Co Carcinogens in the Uranium Mine Environment." to be presented at the International Conference on Occupational Radiation Safety in Mining". Toronto, October 1984 (with R. Marchant).

"Conceptual Design for Disposal of Uranium Refinery Wastes in Mined Limestone Caverns." Presented at Health Physics Society Annual Meeting, New Orleans, June 1984 (with G. Case, J. Davis, D. Moffet).

"ALARA Analysis for the Decommissioning of the Beaverlodge Uranium Mine and Mill Site." Presented at Health Physics Society Annual Meeting, New Orleans, June 1984, (with V.J. Cassaday, R.A. Knapp, L.M. Lowe, M.P. Filion).

"Critical Receptor Pathway Analysis for the Decommissioning of the Beaverlodge Uranium Mine and Mill." Presented at Fifth Annual Conference, Canadian Radiation Protection Association, Banff, May 1984. (with V.J. Cassaday, L.M. Lowe and M.P. Filion).

"Design for Radiation Protection in a High Grade Underground Uranium Mine." Presented at Fifth Annual Conference, Canadian Radiation Protection Association, Banff, 4 May 1984.

"TLV's for Non-Standard Work Schedules" Pollution Engineering, November 1983, (with L.M. Lowe).

"Long Term Dose Implications of Accidental Releases from Nuclear Facilities" Presented at Fall Meeting of Air Pollution Control Association, Ontario Section. September 12, 1983, Minett, ON (with D.W. Hopper and L.M. Lowe).

"Air Quality Model Validation Study". Presented at the Seventy-Sixth Annual Meeting of the Air Pollution Control Association, Atlanta, GA, June 1983 (with D.W. Hopper and J.P. Jarrell).

"A Model for the Regional Transport and Cycling of Carbon-14". Present 1 at the Health Physics Society Annual Meeting, Baltimore, MD, June 1983 (with J.M. Scharer and L.M. Lowe).

"Accident Dispersion Modelling - A Simplified Approach". Presented at the Seventy-Sixth Annual Meeting of the Air Pollution Control Association, Atlanta, GA, June 1983 (with D.W. Hopper).

"Calculation of Radiation Exposure in a Case Control Study of Lung Cancers in Port Hope, Ontario". Presented at the Annual Canadian Radiation Protection Association Conference, Toronto, ON, May 1983.(with G. Case and "Environmental Issues Related to Uranium Mining". Presented at the Canadian Nuclear Association Seminar on Uranium and Nuclear Issues, Toronto, ON, November 1982 (with D.M. Gorber).

"Overview of Uranium Tailings Management Practice". Invited paper presented at the International Conference on Radioactive Waste Management, Winnipeg, MA, September 1982 (with R.A. Knapp, B.G. Ibbotson, and L.M. Lowe).

"Assessment of Hypothetical Disposal Facilities for Canada's Low Level Radioactive Waste". Presented at the International Conference on Radioactive Waste Management, Winnipeg, MA, September 1982 (with A. Buchnea, L. Cabeza, E.J. Chart and L.M. Lowe).

"Environmental Considerations Related to Uranium Exploration". Presented at the Third Annual Conference of the Canadian Nuclear Society, Toronto, ON, June 1982 (with B.G. Ibbotson and V.J. Cassaday).

"Design for Radiation Protection in the Mining of High Grade Uranium Ore". Chapter 70 of "Radiation Hazards in Mining - Control, Measurements, and Medical Aspects', the Proceedings of the first International Conference, Colorado School of Mines, Golden, CO, October 1981 (with J. Mernagh and R.T. Torrie).

"The Use of Radon Risk Estimators in Evaluating the Effects of Uranium Mining and Milling Operations". Presented at the Health Physics Society Annual Meeting, Louisville, KT, June 1981 (with L.M. Lowe and R.B. Sutherland).

"Fuel Cycle Risks - The Front End". Presented to the Canadian Nuclear Association Seminar on Nuclear Power Risks in Perspective, Toronto, ON, May 1981 (with S.E. Frost and V.J. Cassaday).

"Potential Health Impacts of Enhanced Radiation Levels in Port Hope". Presented to the Second Annual Meeting of the Canadian Radiation Protection Association, Ottawa, ON, May 1981 (with L.M. Lowe, R.B. Sutherland and E.J. Chart).

"The Canadian Experience - A Review of Environmental Considerations Associated with Uranium Mining Operations in Elliot Lake". Presented at the operation Action UP Conference on Uranium Mining and Radiation Safety at Michigan Tech University, Houghton, MI, September 1980 (with D.M. Gorber and B.G. Ibbotson).

"Development and Use of Radon Source Terms in Environmental Impact Assessments of Uranium Mines and Mills". Presented to the Health Physics Society Annual Meeting, Seattle, WA, July 1980 (with L.M. Lowe, V.J. Cassaday, J. Nantel and J. Archibald).

"Radium in Water, Sources, Levels and Effects". Presented at the Annual Conference of the Ontario Section, American Waterworks Association, Toronto, ON, April 1980 (with D.M. Gorber and B.G. Ibbotson).

"Radiological Evaluation of a Uranium Mines Expansion - A Case Study". Presented to the American Nuclear Society, San Francisco, CA, November 1979 (with L.M. Lowe).

"Environmental Assessments - A Consultant's Viewpoint". Presented at the Canadian Nuclear Association International Conference, Toronto, ON, June 1979.

"Radiological Monitoring of Uranium Fuel Processing Facilities". Seminar at Environment Canada, March 1979.

"Environmental Factors Related to the Development of a New Uranium Refinery". Presented at the Eighth Annual Hydrometallurgical Meeting, Montreal, PQ, August 1978 (with J.P. Jarrell).

"Radium Removal - Perspectives for the Future". Presented to the Canadian Uranium Producers' Metallurgical Committee Workshop on Radium-226 Control, Ottawa, ON, October 1977 (with R.A. Knapp).

"Industrial Hygiene Survey of Uranium Mining and Milling Industry in Canada". Seminar at Canada Centre for Mineral and Energy Technology, Ottawa, ON, July 1977.

Taught course in Air Pollution Control Engineering at University of Toronto (Spring 1976, Spring 1977). Offered by Department of Civil Engineering to fourth year and gradute students.

"The Role of Noise in Environmental Impact Statements". Presented to a joint meeting of the PCAO and Ontario APCA, Toronto, ON, November 1976.

"Comparison of Environmental Factors Relating to Alternative Sites for a Nuclear Generating Station in New Brunswick". Presented at Environment II, Association of Consulting Engineers of Canada, Montreal, PQ, September 1976 (with R.D. Gillespie and E. Koczkur).

"Noise Pollution". Seminar #4 - Man and the Environment, Conservation Council of Ontario, February 1976.

"Sources and Emissions of Atmospheric Mercury". Presented at the International Conference on Heavy Metals in the Environment, Toronto, ON, October 1975 (with D.M. Gorber and E. Koczkur).

"Air Environment Review of Asbestos, Mercury and Lead". Presented at the Industrial Waste Conference, Toronto, ON, June 1975 (with D.M. Gorber and E. Koczkur).

"Role of Consulting Engineer in Air Pollution Control". Seminar at Centre for Air Measurement Studies at Pennsylvania State University, 1974.

"Review of Noise in Canada - Attitudes and Levels". Presented at the Ontario - Quebec APCA Joint Fall Meeting, Ottawa, ON, 1974 (with E. Koczkur).

"Stack Testing, Odour Measurement and In-plant Measurements". Joint seminar of the MOE and PCAO, Toronto, ON, 1974 (with E. Koczkur).

"Review of Industrial and Environmental Noise Concerns". Presented at the AIME Fall Meeting, Hamilton, ON, 1973 (with E. Koczkur).

Ph.D. Thesis Topic: "The Thermodynamics of Self-Organizing Systems". (Spring 1973) - (A new optimal principal in non-equilibrium thermodynamics was developed and subsequently applied to study self-organizing systems).

Edwin Tanner Still

Professional Biography

1. Personal Vitae: Born 2 November 1935, Walton County, Georgia, citizen U.S.A. Married, two children.

2. Education:

   Monroe High School 1950-53.

   University of Georgia, Athens, Georgia, D.V.M. 1959. Attendance 1953-59

   University of Rochester, Rochester, New York, M.S. 1964. Attendance 1963-64

   Course work at University of Georgia consisted of 90 quarter hours of pre-veterinary school requirements in inorganic and organic chemistry, botany, physics, zoology, literature, mathematics, animal sciences, etc., at undergraduate level and approximately 240 quarter hours in the School of Veterinary Medicine.

   Course work at the University of Rochester School of Medicine and Denistry was in radiation biology and consisted of courses in environmental health, nuclear physics, epidemiology, statistics, biological effects of radiation, toxicology, aerosols, health physics, etc.

3. Professional Experience:

1959-61	Base Veterinarian, Ellington AFB, Texas
1961-63	Base Veterinarian, McGuire AFB, New Jersey
1964-67	Research Investigator, Radiobiology Branch, School of Aerospace Medicine, Brooks AFB, Texas
1967-69	Senior Research Investigator, Mammalian Radiobiology Section, Biological and Medical Sciences Division, Naval Radiological Defense Laboratory, San Francisco, California
1967-69	Air Force Liaison Officer, Naval Radiological Defense Laboratory, San Francisco, California
1969-75	Technical Representative, Biomedical Programs, Divison of Biomedical and Environmental Research, U.S. Atomic Energy Commission, Washington, D.C. (Energy Research and Development Administration)

1975-76	Chairman, Radiation Biology Department, Armed Forces Radiobiology Research Institute, Bethesda, Maryland 20014
1976-78	Research Program Coordinator, Armed Forces Radiobiology Research Institute, Bethesda, Maryland 20014
1978-82	Assistant to the Director (Biomedical Effects), Defense Nuclear Agency, Washington, D.C. 20305
1982-83	Senior Physical Scientist, Corporate Medical Department, Environment and Health Management Division, Kerr-McGee Corporation, Oklahoma City, Oklahoma 73125
1983-84	Vice President, Environmental Affairs, Environment and Health Management Division, Kerr-McGee Corporation, Oklahoma City, Oklahoma 73125
1984 to Present	Vice President and Director, Environment and Health Management Divison, Kerr-McGee Corporation, Oklahoma City, Oklahoma 73125

4. Professional Affiliations:

American Veterinary Medical Association
D.C. Verterinary Medical Association
Oklahoma Veterinary Medical Association
Sigma Xi
Health Physics Society

5. Military Service:

U. S. Air Force, September 1959-October 1979. Retired, Colonel

6. Papers and Abstracts:

(1) "The Effect of Massive Doses of 32 MeV Protons and ^{60}Cobalt Gamma Radiation on Serum Enzyme Levels of Whole-Body Irradiated Primates," G.V. Dalrymple, I. L. Lindsay, J. J. Ghidoni, H. L. Kundel, and E. T. Still. SAM-TR-65-22, 1965.

(2) Ibid, Journal of Nuclear Medicine, 6, 588-593, August 1965.

(3) "Some Effects of Whole-Body 32 MeV Proton Irradiation on Primates," G. V. Dalrymple, I. L. Lindsay, J. J Ghidoni, H. L. Kundel, and E. T. Still, R. Jacobs, R. Hall, G. Williams, and I. L. Morgan. SAM-TR-65-43, 1965.

(4) "Early Physiologic Changes in Primates Following Mixed Gamma-Neutron Pulsed Radiation," E. A. Rice, D. S. Sawyer, E. T. Still, and S. E. Beard. SAM-TR-65-31, 1965.

(5) "Clinical Aspects of Proton Irradiation," G. V. Dalrymple, I. L. Lindsay, J. J. Ghidoni, H. L. Kundel and E. T. Still, Abstract, 13th Annual Meeting, Radiation Research 25, May 1965.

(6) "Some Effects of Whole-Body 32 MeV Proton Irradiations on Primates,", G. V. Dalrymple, I. Lindsay, J. J. Ghidoni, H. L. Kundel, E. T. Still, R. Jacobs, and I. L. Morgan. Radiation Research 28, 406-433, 1966.

(7) "Dose-Rate Effect on Acute Mortality of Mice Following 138 MeV Proton or 2 MeV X-Ray Irradiation," J. E. Traynor and E. T. Still. Abstract, 15th Annual Meeting, Radiation Research Society, May 1967.

(8) "Dose-Rate Studies with Sheep and Swine," E. J. Ainsworth, N. P. Page, J. F. Taylor, G. F. Leong, and E. T. Still. In Proceedings of a Symposium, "Dose Rate in Mammalian Radiation Biology," 29 April - 1 May 1968, U. of Tenn., AEC, Agriculture Research Laboratory, Oak Ridge, Tennessee.

(9) Ibid, NRDL-TR-68-96, June 1968.

(10) "Reexamination of Biological Recovery Rates and Equivalent Residual Doses," G. F. Leong, E. J Ainsworth, J. F. Taylor and E. T. Still. In Proceedings of a Symposium, "Radiological Protection of the Public in a Nuclear Mass Disaster," Interlaken, Switzerland, 26 May - 1 June 1968.

(11) "Acute Mortality and Recovery Studies in Burros Irradiated with 1 MvP X-Rays," E. T. Still, N. P. Page, J. F. Taylor, W. G. Wisecup, E. J. Ainsworth and G. F. Leong. NRDL-TR-68-101, September 1968.

(12) "Dose-Rate Effect on LD50 (30) in Mice Exposed to ^{60}Cobalt Gamma Irradiation," J. E. Traynor and E. T. Still, SAM-TR-68-97, October 1968.

(13) "Hematological Response in Sheep Given Protracted Exposures to ^{60}Cobalt Gamma Radiation," E. T. Still, S. T. Taketa, E. J. Ainsworth, G. F. Leong, and J. F. Taylor, NRDL-TR-69-6, January 1969.

(14) "Survival Time and Hematological Response in Sheep Subjected to Continuous Gamma Irradiation," E. T. Still, J. F. Taylor, G. F. Leong, and E. J. Ainsworth. Abstract, 17th Annual Meeting, Radiation Research Society, May 1969.

(15) "Survival Time and Hematological Responses in Sheep Subjected to Continuous ^{60}Cobalt Gamma Irradiation," E. T. Still, J. F. Taylor, G. F. Leong, and E. J. Ainsworth, NRDL-TR-69-29, June 1969.

(16) "Mortality of Sheep Subjected to Acute and Subsequent Protracted Irradiation," E. T. Still, J. F. Taylor, G. F. Leong, and E. J. Ainsworth, NRDL-TR-69-32, January 1969.

(17) "Acute Lethality and Recovery of Goats after 1 MvP X-Irradiation," J. F. Taylor, E. T. Still, N. P. Page, G. F. Leong, and E. J. Ainsworth. NRDL-TR-69-32, January 1969.

(18) "The Effect of Exposure Rate on Radiation Lethality in Swine," J. F. Taylor, E. T. Still, E. J. Ainsworth, and G. F. Leong. NRDL-TR-69-96, July 1969.

(19) "The Influence of the Amount of Initial Radiation Exposure on the Recovery Pattern in Sheep," E. T. Still, J. F. Taylor, G. F. Leong, and E. J. Ainsworth, NRDL-TR-69-97, July 1969.

(20) "Acute Mortality and Recovery Studies in Burros Irradiated with 1 MvP X-Rays," E. T. Still, N. P. Page, J. F. Taylor, W. G. Wisecup, E. J. Ainsworth, and G. F. Leong. Radiation Research 39 580-593 (1969).

(21) "Inter-Laboratory Comparison of Mortality of Sheep Exposed to ^{60}Cobalt Gamma Rays," T. S. Mobley and E. T. Still. Joint AFWL-TR-69-48 (1969).

(22) "Acute Lethality and Recovery of Goats after 1 MvP X-Irradiation," J. F. Taylor, E. T. Still, N. P. Page, G. F. Leong, and E. J. Ainsworth. Radiation Research 45, 110-126 (1971).

(23) "Vulnerability of Livestock to Fallout Gamma Radiation," E. T. Still and N. P. Page. In Proceedings of a Symposium on Survival of Food Crops and Livestock in the Event of Nuclear War, Brookhaven National Laboratory, Upton, New York. AEC Symposium Series 24, 648-655 (December 1971).

(24) "Environmental Effects of Nuclear Industry," E. T. Still, General Topical Session at the 45th Annual Meeting of the South Carolina Academy of Science, March 23-25, 1972. Bulletin of the S. C. Academy of Sciences, XXXIV, 48-54, 1972.

(25) "Factors Modifying the Response of Large Animals to Low-Intensity Radiation Exposure," N. P. Page, and E. T. Still, In Proceedings of the National Symposium on Natural and Man-made Radiation in Space, Las Vegas, Nevada, March 1-5, 1971. NASA TM Z-2440, 622-632 (January 1972).

(26) "Radon Daughters Research and Litigation Issues," E. T. Still and J. C. Stauter. American Mining Congress Annual Meeting, Phoenix, Arizona, September 1985.

7. Representative Presentations of Academic Nature

(1) Lecturer in Radiation Biology, Health Physics, and Radiation Standards for U.S. Air Force School of Aerospace Medicine in courses for: Flight Medical Officers Training; Flight Nurses Training; Allied Officers Advanced Medical Training; NASA Astronaut Training; Medical Service Corps Engineer Training; and Laboratory Animal Medicine Graduate Course for Veterinarians (1964-67).

(2) Lecturer on Laboratory Animal Models for Biomedical Research for Laboratory Animals Training Course, Animal Health Division, Agricultural Research Service, U.S. Department of Agriculture (1970).

(3) Lecturer on Low-Dose Ionizing Radiation for military physicians course of the Medical Effects of Nuclear Weapons at Armed Forces Radiobiology Research Institute (1979).

(4) Lecturer on Fertile Women and Occupational Radiation Exposure Considerations, AFRRI (1976).

(5) Lecturer on Development of Nuclear Weapons History-Policy-Doctrine for Uniformed Services University of Health Sciences (1978).

(6) Symposium Session Chairman and Working Group Chairman on Fallout-Radiation Effects on Livestock at Brookhave National Laboratory, New York for Symposium entitled, "Survival of Food Crops and Livestock in the Event of Nuclear War" (1971).

8. Representative Participation on Committees, Interagency Panels, Groups

(1) Member, Interdepartmental Committee on National Blood Program Research (1972-73).

(2) Liaison member, Hematology Study Section, National Institutes of Health (1971-75).

(3) Member, Joint Technical Coordinating Group for Munitions Effectiveness - Ad Hoc Working Group For Medical and Environmental Evaluation of Depleted Uranium, and contributor to Special Report (1973-74).

(4) Member of special committee convened by Assistant Secretary of Army to perform a Hazard Evaluation of the Use of Depleted Uranium Penetrators, and contributor to report on biological effects and dose rates (1978-79).

(5) Invited Scientific Reviewer for Energy Research and Development Administration Research Programs on Internal Emitters (1976).

(6) Expert witness for Puerto Rico Water Resources Authority, Commonwealth of Puerto Rico, at Environmental Quality Board hearing on radiation effects of nuclear power plants (1972).

(7) Designated U.S. Air Force expert consultant on medical effects of depleted uranium to the Department of State for meetings with NATO allies (1978).

(8) Member, Radiation Safety Audit and Inspection Team for Enewetak Atoll (1978-79).

(9) DoD representative to Science Working Group of the Interagency Task Force on the Health Effects of Ionizing Radiation (1978-79).

(10) Designated DoD representative to Interagency Committee on Transuranic Element Soil Contamination Guidelines (1976-79).

(11) Designated DoD member of Interagency Committee on Federal Research into the Biological Effects of Ionizing Radiation (1979).

(12) Designated DoD member of the Committee for Development of the Federal Strategy for Research into the Biological Effects of Ionizing Radiation (1979).

(13) Member, Committee on Metabolism and Dosimetry of High - LET Radionuclides, U. S. Environmental Protection Agency National Workshop on Radioactivity in Drinking Water (1983-84).

(14) Member, National Environmental Studies Project Taskforce, Atomic Industrial Forum, Washington, D.C. (1983-85).

(15) Member, Task Group on Uranium Mining and Milling - Radiation Safety Programs, National Council on Radiation Protection and Measurements, Bethesda, Maryland (1984 to present).

ETS-2/27/85

feelers incorrect with data

APPENDIX B

GAMMA SURVEY OF THE KRESS CREEK AREA

Over the course of the fall of 1985 Kerr-McGee undertook a systematic survey of the gamma exposure rates for all properties in the vicinity of Kress Creek for which permission to survey could be obtained.[1] The survey staff prepared a map of each property and then surveyed the property along a rectangular grid with a spacing of five feet.[2] Gamma exposure rate readings were made at one meter from the ground surface at each grid intersection using an Eberline PRM-7 gamma meter. Any readings in excess of 30 ur/h were recorded on the map of the property.

The survey data provide detailed information as to the gamma field along the Creek. In particular, the measurements enable not only the identification of points with elevated gamma readings, but also the areal extent and distribution of regions with elevated readings. This was accomplished by using the grid measurements to construct isopleths defining the contours of the gamma radiation field.

---

[1] The survey was undertaken for property adjacent to the Creek from the storm-sewer outfall to the confluence with the West Branch of the DuPage River. Permission to survey was obtained for 22 of the 28 properties along the Creek, or approximately 80% of all properties.

[2] In the case of certain of the non-residential properties, such as the park areas, the survey grid had a spacing of ten feet in the vicinity of the Creek. The larger spacing was used because these properties were largely unaffected.

Table B-1 sets out the total area from all the surveyed properties that were found to have radiation intensities from 50 to 99 ur/h, from 100 to 149 ur/h, and greater than 150 ur/h. As may be seen, the vast preponderance of the regions with gamma intensities greater than 50 ur/h were found to have a gamma intensity in the lowest intensity range (50 to 99 ur/h). In fact, only about three percent of the properties with gamma intensities in excess of 50 ur/h were found to have an intensity greater than 150 ur/h. And the percentage of the total area along the Creek that has elevated readings (above 50 ur/h) is minuscule.[1] The data thus confirm that markedly elevated gamma readings affect only a slight portion of the area along the Creek.

The maps show that the regions with elevated readings are isolated from each other. Table B-2 sets out information as to the size of the regions along the Creek for which elevated gamma readings were observed. The regions that have a gamma intensity of 150 ur/h or greater were observed to have an average area of 450 ft^2, and the <u>maximum</u> area of any such region was only 600 ft^2. The data thus confirm that the most elevated gamma readings affect only small and discrete regions in the Creek vicinity.

---

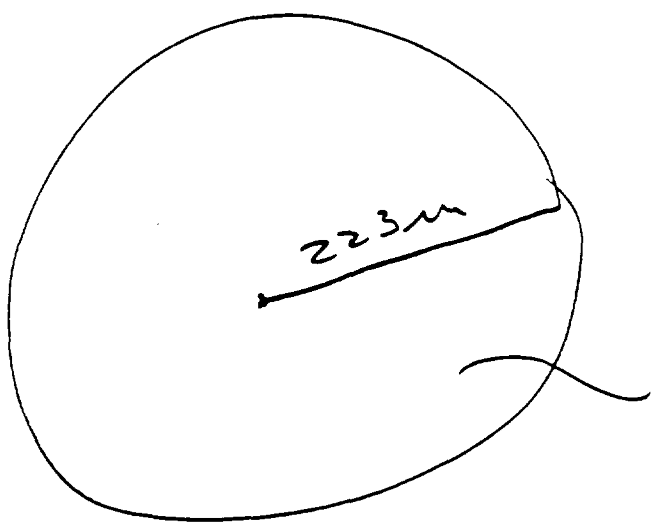
[1] The total area of the surveyed properties is about 3,200,000 ft^2. Thus the total area with gamma readings in excess of 50 ur/h -- about 50,600 ft^2 -- represents approximately 1.6% of the total area surveyed. The total area with readings in excess of 150 ur/h constitutes only 0.05% of the total area surveyed.

TABLE B-1

TOTAL AREA OF ELEVATED GAMMA REGIONS

	Total Area (ft^2)	Percentage of Total Area With Readings Greater Than 50 ur/h	Percentage of Total Area Surveyed
50 to 99 ur/h	44700	88.3	1.40
100 to 149 ur/h	4300	8.5	0.13
≥ 150 ur/h	1600	3.2	0.05
	4700 m^2		

~40 m



$A = \pi (223)^2$

TABLE B-2

AREA OF INDIVIDUAL ELEVATED GAMMA REGIONS

	Minimum Area (ft^2)	Average Area (ft^2)	Maximum Area (ft^2)
50 to 99 uR/h	100	2000	6600
100 to 149 uR/h	150	500	1500
≥ 150 uR/h	100	450	600

50 uR/h

~ 12

50u / J

APPENDIX C

ESTIMATION OF INDOOR RADON AND THORON LEVELS

Various authors have calculated the radon and thoron levels inside structures arising from a flux into the structure from adjacent materials. Porstendorfer, et al. (1978); Stranden (1980); Krisiuk (1980); Meggitt (1983); and Swedjemark (1985). Expressed in its simplest fashion, the steady-state concentration of radon or thoron inside a house can be estimated from the following equation:

$$C = \frac{J \times A}{V(\lambda_v + \lambda_r)} \quad [pCi/m^3] \qquad (C.1)$$

where

- C = the indoor concentration of radon or thoron $[pCi/m^3]$
- J = the radon or thoron flux per unit area of the structure $[pCi/m^2 s]$
- A = source area $[m^2]$
- V = the volume of the room or structure $[m^3]$
- λ_v = the air exchange rate of the structure $[s^{-1}]$
- λ_r = the radioactive decay constant of radon or thoron $[s^{-1}]$.

Although the equation neglects the presence of radon or thoron in outdoor air, this approximation is usually a good assumption for residences (Meggitt, 1983).

The calculation of the daughter concentrations that are derived from the parent radon or thoron concentration involves the solution of differential equations. Krisiuk (1980) has solved these equations and has conveniently summarized the values in terms of an equilibrium factor (F) for both radon and thoron for different air-change rates for a home. Possible mechanisms of removal of the radon and thoron daughters, such as plateout on walls or floors, were not evaluated by Krisiuk. The predicted F values are thus probably higher than the actual values and the formulation thus tends to overestimate the daughter concentrations.

The concentration of radon or thoron daughters, expressed in working levels (WL), is given by:

$$\text{WL (radon)} = \frac{\text{F(radon)} \times \text{C(radon)}}{100} \qquad \text{(C.2)}$$

$$\text{WL (thoron)} = \frac{\text{F(thoron)} \times \text{C(thoron)}}{7.5} \qquad \text{(C.3)}$$

The different denominators in equations C.2 and C.3 arise from the definition of 1 WL -- 1.3×10^5 MeV of potential alpha energy per liter of air. This is equivalent to 100 pCi/L and 7.5 pCi/L of radon and thoron, respectively, in equilibrium (F = 1) with their daughters (UNSCEAR, 1977; ICRP, 1981).

The equations to calculate radon flux (p. 25),[1] radon or thoron concentration (C.1), and working levels (C.2

---

[1] However, the attenuation due to the walls of the structure must be taken into account when estimating the flux J. As discussed above, a barrier is 77 times more effective in attenuating thoron than in attenuating radon. *See supra* p. 26 & note 1.

or C.3), when coupled with the equilibrium factors (F) given by Krisiuk enable the estimation of the radiological environment in a home. While the methodology does not account for all the mechanisms affecting indoor levels, it does provide reasonable estimates.

APPENDIX D

REFERENCES

Cember, H. 1969. "Introduction to Health Physics." Pergamon Press, 420 pp.

Chambers, D.B., Mernagh, J.R., and Torrie, R.T., 1981. "Design for Radiation Protection in the Mining of High Grade Uranium Ore." In: Proceedings of the International Conference on Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, October 4-9, Golden, Colorado. (M. Gomez, ed.). Published by Society of Mining Engineers, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., New York, N.Y.

Crouch, E.A.C. and Wilson, R., 1982. "Risk/Benefit Analysis." Ballinger Publishing Company, Cambridge.

Department of the Army, Chicago District, Corps of Engineers, 1975. "Flood Plain Information, West Branch DuPage River and Tributaries, DuPage County, Illinois."

Electric Power Research Institute (EPRI), 1985. "Proceedings: Indoor Air Quality Seminar--Implications for Electric Utility Conservation Programs." Prepared by William I. Whiddon and Associates, and Hart, McMurphy and Peaks, Inc. EPRI Report EA/EM-3824.

Frigerio, N.A., Larson, T.J. and Stowe, R.S., 1978. "Thorium Residuals in West Chicago, Illinois." Argonne National Laboratory, NUREG/CR-0413, ANL/ES-67.

Gesell, T.F., 1983. "Background Atmosphere Rn-222 Concentrations Outdoors and Indoors: A Review." Health Physics, Vol. 45, pp. 289-302.

Gunning, G. and Scott, A.G., 1982. "Radon and Thoron Daughters in Housing." Health Physics, Vol. 42, No. 4, pp. 527-528.

Illinois Department of Transportation, 1986. Letter from Phillip P. Madonia, Chief, Safety Data and Data Services, Division of Traffic Safety, January 21.

International Commission on Radiological Protection (ICRP), 1977. "Recommendations of the International Commission on Radiological Protection." ICRP Publication 26, Annals of the ICRP, Vol. 1, No. 3.

International Commission on Radiological Protection (ICRP), 1979. "Limits for Intake of Radionuclides by Workers." ICRP Publication 30, Supplement to Part 1, Annals of the ICRP, Vol. 3, No. 1-4.

International Commission on Radiological Protection (ICRP), 1981. "Limits for Inhalation of Radon Daughters by Workers." ICRP Publication 32, Annals of the ICRP, Vol. 6, No. 1.

International Commission on Radiological Protection (ICRP), 1985. "Quantitative Bases for Developing a Unified Index of Harm." ICRP Publication 45, Annals of the ICRP, Vol. 15, No. 3.

Jensen, L., Regan, G., Goranson, S., and Bolka, B., 1984. "Ambient Monitoring of Airborne Radioactivity Near a Former Thorium Processing Plant." Health Physics, Vol. 46, pp. 1021-1033.

Krisiuk, E.M., 1980. "Airborne Radioactivity in Buildings." Health Physics, Vol. 38, pp. 199-202.

Meggitt, G.C., 1983. "Radon and Thoron in Buildings." Radiation Protection Dosimetry, Vol. 5, pp. 5-17.

Myrick, T.E., Berven, B.A., and Haywood, F.F., 1981. "State Background Levels: Results of Measurements Taken During 1975-79." Oak Ridge National Laboratory, ORNL/TM-7343. See also Health Physics, Vol. 45, pp. 631-642.

National Council of Radiation Protection and Measurements (NCRP), 1975. "Natural Background Radiation in the United States." NCRP Report No. 45.

National Council on Radiation Protection and Measurements (NCRP), 1984b. "Evaluation of Occupational and Environmental Exposure to Radon and Radon Daughters." NCRP Report No. 78.

National Council on Radiation Protection and Measurements (NCRP) 1985. "General Concepts for the Dosimetry of Internally Deposited Radionuclides." NCRP Report No. 84.

Nuclear Energy Agency (NEA), 1983. "Dosimetry Aspects of Exposure to Radon and Thoron Daughter Products." Report by a Group of Experts of the OECD-NEA, Paris.

Oak Ridge Associated Universities (ORAU), P.W. Frame, et al., 1984. "Comprehensive Radiological Survey of Kress Creek, West Chicago Area, Illinois." Prepared for the Division of Fuel Cycle and Material Safety, U.S. Nuclear Regulatory Commission.

Oser, B.L., 1978. "Benefit/Risk: Whose? What? How Much?" Food Technology, Vol. 32, pp. 55-58.

Pochin, E.E., 1978. "Why Be Quantitative About Radiation Risk Estimates." Lecture No. 2 in the L.S. Taylor Lecture Series in Radiation Protection and Measurement, National Council on Radiation Protection and Measurement, Washington, DC.

Porstendorfer, J., Wicke, A. and Schraub, A., 1978. "The Influence of Exhalation, Ventilation and Deposition Processes Upon the Concentration of Radon, Thoron and Their Decay Products in Room Air." Health Physics, Vol. 34, pp. 465-473.

Schery, F.D., 1985. "Measurements of Airborne Lead-212 and Radon-220 at Varied Indoor Locations within the United States." Health Physics, Vol. 49, pp. 1061-67.

Starr, C., and Whipple, C., 1980. "Risks of Risk Decisions." Science, Vol. 208, pp. 114-119.

Stranden, E., 1980. "Thoron and Radon Daughters in Different Atmosphere." Health Physics, Vol. 3, pp. 777-785.

Swedjemark, G.A., 1985. "Radon and Its Decay Products In Housing." Doctoral Dissertation, Department of Radiation Physics, University of Stockholm.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1977. "Sources and Effects of Ionizing Radiation." United Nations Publications.

U.S. Department of Energy (DOE), 1983. "Pathways Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites." Argonne National Laboratory, U.S. DOE Report ORO-832.

U.S. Department of Labor, 1985. "Occupational Injuries and Illnesses in the United States by Industry, 1983." Bureau of Labor Statistics, Bulletin 2236.

U.S. Department of Labor, 1983. "Occupational Injuries and Illnesses in the United States by Industry, 1981." Bureau of Labor Statistics, Bulletin 2164.

U.S. Department of Labor, 1981. "Occupational Injuries and Illnesses in 1979: Summary." Bureau of Labor Statistics, Bulletin 2097.

U.S. Environmental Protection Agency (EPA), 1983. "Final Environmental Impact Statement Standards for the Control of Byproduct Materials from Uranium Ore Processing (40 CFR 192)." U.S. EPA Report EPA-520/1-83-008-1, and -2.

U.S. Environmental Protection Agency, 1982. "Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192). U.S. EPA Report EPA 520/4-82-013-1.

U.S. Nuclear Regulatory Commission (NRC), 1980. "Final Generic Environmental Impact Statement on Uranium Mining." NUREG-0706.

U.S. Nuclear Regulatory Commission (NRC), 1986. "10 CFR Parts 19, et al., Standards for Protection Against Radiation; Proposed Rule." 51 Fed. Reg. 1092, 9 January 1986.

Wilson, R., 1979. "Analysing the Daily Risks of Life." Technology Review, February 1979.

B

! denies, in part, Licensee's
86 Memorandum and Order.

ATOMIC SAFETY AND
ENSING BOARD

on J. Wolfe, Chairman
INISTRATIVE JUDGE

scar H. Paris
INISTRATIVE JUDGE

rick J. Shon
INISTRATIVE JUDGE

Cite as 23 NRC 799 (1986) LBP-86-18

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:

John H Frye, III, Chairman
Dr. James H. Carpenter
Dr. Jerry R. Kline

In the Matter of | **Docket No. 40-2061-SC**
(ASLBP No. 84-502-01-SC)

KERR-McGEE CHEMICAL CORPORATION
(Kress Creek Decontamination) | **June 19, 1986**

Upon consideration of an Order to Show Cause issued to require preparation of a remedial action plan to clean up certain radiological contamination, Licensing Board rules that:

1. Jurisdiction exists under the Atomic Energy Act independently of the Uranium Mill Tailings and Radiation Control Act to require that a remedial action plan be prepared which is necessary or desirable to protect health because of the radiological contamination of Kress Creek and the West Branch of the DuPage River.
2. The radium-in-soil standard promulgated by the U.S. Environmental Protection Agency under the Uranium Mill Tailings and Radiation Control Act is not appropriate to protect health in the situation posed by this radiological contamination.
3. Part 20 of the Commission's regulations contains numerical radiological dose limitations which are appropriate to protect health in the situation posed by this radiological contamination.

4. The record in this proceeding does not demonstrate that the Part 20 numerical radiological dose limitations are exceeded as a result of this contamination.

Order to Show Cause dismissed.

NUCLEAR REGULATORY COMMISSION: JURISDICTION

The regulatory scheme set forth in Part 20 of the Commission's regulations clearly indicates that jurisdiction exists to regulate a licensee's activities to control radiological doses regardless of whether those doses result from material which may be classified as special nuclear, source or byproduct material.

URANIUM MILL TAILINGS AND RADIATION CONTROL ACT (UMTRCA): RADIUM-IN-SOIL STANDARDS

The radium-in-soil standards promulgated by the U.S. Environmental Protection Agency under UMTRCA are not appropriate to protect health in the situation presented by this radiological contamination because the principal hazard is gamma radiation, not radon or thoron.

ATOMIC ENERGY ACT: DOSE LIMITATIONS

The numerical radiological dose limitations contained in Part 20 of the NRC regulations are applicable to materials licensees and are appropriate to protect health where the principal hazard is gamma radiation.

APPEARANCES

Stephen H. Lewis, Deputy Assistant Chief Hearing Counsel, and **Henry J. McGurren** and **Mary E. Wagner**, Counsel, Bethesda, Maryland, for the United States Nuclear Regulatory Commission Staff.

Peter J. Nickles, Richard A. Meserve, and **David P. King**, Washington, D.C., for the Kerr-McGee Chemical Corporation.

INITIAL DECISION
(Order to Show Cause)

INTRODUCTION

This proceeding was initiated by an Order to Show Cause (Order) issued by NRC Staff to Kerr-McGee Chemical Corporation (Kerr-McGee) on March 2, 1984. On March 12, Kerr-McGee filed an answer to the Order and demanded a hearing. On June 28, the Commission referred this matter to the Chairman of the Atomic Safety and Licensing Board Panel to appoint an atomic safety and licensing board to conduct any necessary proceedings under 10 C.F.R. Part 2, Subpart A, and to consider and decide whether, on the basis of the allegations of §§ II and III of the Order, Kerr-McGee should be required to take the actions specified in § IV.[2]

THE ORDER TO SHOW CAUSE

Kerr-McGee holds a license authorizing possession of unlimited amounts of thorium at its West Chicago Rare Earths Facility. This facility ceased operations in December 1973. Section II of the Order alleges that a portion of the wastes from that site have been disposed of by discharge to Kress Creek and thence to the West Branch of the DuPage River, either by a storm sewer which enters the creek 0.7 kilometer south of the site, or by a drainage ditch. Section II notes that from this point the Creek flows for about 2 kilometers to its confluence with the West Branch at the DuPage River. Section II goes on to recite the history of the discovery of the contamination of the Creek and River.[3]

Section III begins by noting that a comprehensive radiological survey has been performed at the instance of the Staff. The survey was designed to determine direct radiation levels and the depth distribution of the contamination in the stream beds and along the banks. Section III alleges that the survey revealed the presence of thorium and its daughters essentially in secular equilibrium. It summarizes the survey results and notes that many of the highest concentrations were found in areas near

---

[1] *See* 49 Fed. Reg. 9288 (Mar. 12, 1984).

[2] On June 29, 1984, this Board was established by the Chairman, Atomic Safety and Licensing Board Panel (49 Fed. Reg. 27,863 (July 6, 1984)), and reconstituted on February 4, 1986 (51 Fed. Reg. 5007 (Feb. 10, 1986)).

[3] For convenience, we will refer to both these streams as Kress Creek or the Creek.

the storm sewer outfall. This section concludes by alleging that the contamination exceeds the standards promulgated by the U.S. Environmental Protection Agency (EPA) under the Uranium Mill Tailings and Radiation Control Act (UMTRCA) for unrestricted use of areas on which thorium processing wastes have been disposed (40 C.F.R. Part 192, Subparts B and E),[4] that NRC is responsible for enforcing these standards, and that cleanup is required.

Section IV required Kerr-McGee to show cause why it should not be required to prepare a remedial action plan for the cleanup and disposal of the contaminated material and expeditiously execute the plan following NRC approval. There is no allegation in the Order of any violation of a regulation or license condition. Kerr-McGee responded to the Order with an answer (and subsequently an amended answer) and a Demand for Hearing.[5]

Two petitions to intervene were received, one from the People of the State of Illinois and Illinois Department of Nuclear Safety (collectively referred to as "the People") and the other from the Nicheren Shoshu Temple (NST).[6] Kerr-McGee did not object to the petitions.[7] The NRC Staff asserted[8] that both were late-filed, but concluded, after balancing the five factors set out in 10 C.F.R. § 2.714(a) for nontimely intervention petitions, that they should be granted. We concluded that the petitions were timely, that each party had standing, and that each had submitted at least one acceptable contention. We granted party status to the People and NST at the first prehearing conference, held in Chicago, August 22, 1984.[9]

The People filed six contentions. Contention 1 raised the possibility that chemical pollutants may exist in Kress Creek which should be considered in any cleanup plan. Contention 6 was duplicative of the Order. Contentions 2 through 5 raised matters concerning disposal of the material excavated from the Creek. Contentions 1 and 6 were admitted, while a ruling on Contentions 2 through 5 was withheld pending a

[4] We will refer to this standard as the radium-in-soil standard.

[5] Answer and Demand for Hearing of March 19, 1984; Amended Answer of October 10, 1984.

[6] People of the State of Illinois Petition to Intervene, July 10, 1984; Petition for Leave to Intervene, July 11, 1984.

[7] Answer by Kerr-McGee Chemical Corporation to the People of the State of Illinois Petition for Leave to Intervene, July 25, 1984; Answer by Kerr-McGee Corporation to the Petition for Leave to Intervene filed by Nicheren Shoshu Temple, July 25, 1984.

[8] NRC Staff Response to Petitions of the Nicheren Shoshu Temple and the People of the State of Illinois for Leave to Intervene, July 30, 1984, at 5-9.

[9] Tr. 25-26; Unpublished Prehearing Conference Memorandum and Order of September 7, 1984.

determination that Kerr-McGee must prepare a cleanup plan and pending a resolution of the dispute concerning disposition of the tailings located at the West Chicago site.[10]

We dismissed Contentions 1 and 6 in LBP-85-48, 22 NRC 843 (1985), as a sanction for failure of the People to comply with our discovery orders contained in LBP-85-38, 22 NRC 604 (1985). In LBP-85-48, we noted the agreement between counsel for Staff and the People that these contentions would not add anything to the hearing. Our action did not dismiss the People as a party and they were free to participate in the hearing. However, they chose not to do so.

The Temple, whose property lies along Kress Creek, filed eight contentions. All of these except Contention 7 were admitted.[11] On April 1, 1985, the Temple withdrew from this proceeding.

The hearing took place at West Chicago, Illinois, on April 28 and in Chicago on April 29 and 30, 1986. We heard limited appearance statements from the City of West Chicago in opposition to the movement of any contaminated materials into the City (Tr. 316-18), from the DuPage County Forest Preserve District asking for information with regard to the contamination (Tr. 318-20),[12] and from the Director of the West Chicago Parks District expressing his desire to know whether the material in the Creek poses a hazard (Tr. 342-43). Although two or three persons who live along the Creek were present and invited to state their views, they did not do so (Tr. 342).

BOARD JURISDICTION

In the initial stages of this proceeding, the parties raised the question of NRC jurisdiction in this matter.[13] On November 27, 1984, Staff, the People and NST (Proponents) jointly filed a motion[14] requesting the disposition of several averments contained in Kerr-McGee's amended answer. These parties asserted that the averments raised affirmative defenses to the Order challenging Staff's authority to take the enforcement action.

---

[10] Unpublished Memorandum and Order of October 22, 1984.

[11] *Id.*

[12] On May 13, 1984, the president of the DuPage County Forest Preserve Commission announced that he was closing a 1-mile stretch of the Blackwell Forest Preserve along the DuPage River because of uncertainty surrounding the contamination in the river banks and sediment. PNO-III-85-45, May 14, 1986.

[13] Unpublished Prehearing Conference Memorandum and Order, September 7, 1984, at 4-5.

[14] Joint Motion for Disposition of Averments, November 29, 1984.

The averments which Proponents wished dismissed state:

> 10. No such Order may be issued by the NRC without a finding of a specific significant risk of health, safety or environmental harm
>
> 11. No such Order may be issued without a complete analysis of the actual risk to the health and safety of the public of compliance with such an Order
>
> 12. No such Order may be issued without a complete analysis of the risk of harm to the environment from compliance with such Order
>
> 13. No such Order may be issued without a complete analysis of the costs and benefits of remedial action, including the impacts upon the communities and individuals affected by compliance with such an Order

Kerr-McGee argued that the averments raised jurisdictional matters which must be addressed by Staff if the Order was to be enforced. Kerr-McGee also asserted that the relief sought — disposition of the averments as a matter of law — was inappropriate because the averments presented mixed questions of law and fact.

We denied the Proponent's motion without prejudice to the filing of properly supported motions for summary disposition.[15] There, we recognized the disparate views held by the parties with respect to the matters which must be proven for the Board to enforce the Order. We requested briefs from the parties on the question of what facts must be shown at hearing for Staff to prevail, and urged the parties to focus on the applicable regulatory standards and any circumstances unique to the Kress Creek situation which might militate against the application of those standards.[16]

In view of our ultimate conclusions that the radium-in-soil standard is not appropriate for application in this situation and that no hazardous condition or threat to health has been demonstrated on this record, we need not recite in detail the controversy on this point. However, it is important to note that Staff conceded, in response to Kerr-McGee's position that UMTRCA could not be retroactively applied, that the radium-in-soil standard was not legally binding in this situation. Staff then based its jurisdictional argument on §§ 62, 63, and 161(b) of the Atomic Energy Act, and argued that the radium-in-soil standard, although not legally binding, was nonetheless appropriate and should be applied.[17]

---

[15] Unpublished Memorandum and Order, December 28, 1984

[16] *Id.*

[17] With regard to the allegations contained in the Order, Proponents and Kerr-McGee agreed that the burden of going forward would be borne by Proponents. There was strong disagreement, however, about whether Kerr-McGee's averments should be characterized as affirmative defenses on which Kerr-

(Continued)

It is also important to note that our jurisdiction does not depend on whether the material in Kress Creek may properly be classified as source or byproduct material. Section 161(b), on which Staff relies, states:

> In the performance of its functions the Commission is authorized to establish by rule, regulation, or order, such standards and instructions to govern the possession and use of special nuclear material, source material, and byproduct material as the Commission may deem necessary or desirable to promote the common defense and security or to protect health or to minimize danger to life or property.

On its face, § 161(b) restricts the Commission's authority to special nuclear, source, and byproduct material. Kerr-McGee is a source material licensee subject to the regulations contained in 10 C.F.R. Part 40. UMTRCA extended NRC's jurisdiction to mill tailings, the waste product of the West Chicago facility which probably contaminated the Creek, by including them in the definition of byproduct material. Given that UMTRCA was conceded to be inapplicable, a question arose concerning NRC jurisdiction with regard to the material in Kress Creek. At the prehearing conference, Staff counsel opined that the material in Kress Creek might be source material, and Staff addressed some testimony to this point at the hearing. This testimony was undoubtedly in response to our statement in our March 22, 1985, Memorandum and Order that "Staff must show that the contamination which it wishes cleaned up is properly classified as source material . . . ." Kerr-McGee regards this statement as *dictum*. Kerr-McGee's Post Hearing Submission at 18 n.1. Whether *dictum* or not, we believe that this statement was in error and that, as will be seen, jurisdiction exists regardless of whether the material may properly be classified as source material. Thus we find it unnecessary to address Staff's testimony that the material is source material.

We regard our statement that Staff must show that the material is source material to be in error for the following reasons. Under 10 C.F.R. § 20.2, Part 20 is applicable to Part 40 licensees. Section 20.3(a)(13)

McGee must present evidence or as jurisdictional issues on which Proponents must bear the burden. The Board indicated that it did not find authority to support Kerr-McGee's view that a specific, significant risk, something more than a hazardous condition to the health and safety of the public or to the environment, must be found if the order is to be enforced. Thus, the Board ruled that Kerr-McGee was to bear the burden of going forward with a showing to sustain its position on this averment. Second Prehearing Conference Memorandum and Order, February 7, 1985, at 9.

The averments posed a legal issue concerning the EPA radium-in-soil standards advanced by the Staff. Kerr-McGee contended that cleanup to those standards could be enforced, if at all, only after the Board had engaged in a balancing of costs and benefits, an analysis not required under § 161(b) of the Atomic Energy Act. Staff's position was predicated upon its view that a cost-benefit analysis by the Board was unwarranted because EPA had already analyzed those considerations in the course of promulgating the radium-in-soil standard. We find it unnecessary to rule on the above controversy because Staff has failed to show that the radium-in-soil standard is appropriate in this situation.

defines "radioactive material" to include such material whether or not subject to the Commission's regulatory authority. Section 20.105(a) requires licensees to restrict their possession and use of radioactive materials so as to ensure that it will be unlikely that any individual member of the public will receive a dose of more than 0.5 rem per year. And § 20.1(c) requires licensees to make every reasonable effort to restrict releases of radioactive materials to levels which are as low as reasonably achievable. Clearly, this regulatory scheme illustrates that jurisdiction exists to regulate radiation hazards caused by a licensee whether or not the hazard results from materials which fall within one of the three categories stated in § 161(b). [18]

Kerr-McGee contests the proposition that the material in the Creek came from its West Chicago facility and thus is its responsibility. However, the uncontradicted evidence indicates that the West Chicago Rare Earths Facility is the only thorium processing plant within 50 miles of Kress Creek. This severely narrows the possible places from which the material may have originated. Kerr-McGee's efforts to establish other possible sources (e.g., spillage from railroad cars at the railroad crossing of Kress Creek close to the storm sewer outfall) are pure speculation. While Staff's testimony on possible pathways the material might have followed into Kress Creek is also speculative, in this case we believe the thing speaks for itself. While recognizing the speculative nature of the testimony on this point, we find that the material in Kress Creek came from the West Chicago facility while it was licensed under the Atomic Energy Act and decide this controversy on the merits of the hazard posed by that material. Findings 1 through 21 support this conclusion.

THE STAFF'S PROPOSED CRITERIA FOR CLEANUP

The Order states:

> the NRC Staff concludes that cleanup of the offsite vicinity properties along Kress Creek and the DuPage River is required and that the following levels of contamination specified in EPA standards are to be used as criteria for the offsite properties:
>
> 1. Five picocuries of radium per gram of soil (pCi/g), averaged over the first 15 centimeters (cm) below the surface, and

[18] Kerr-McGee agrees that "the NRC has authority to issue a customized order directed at a licensee regarding the offsite release of materials that are not themselves source materials." Post Hearing Submission at 19. While Kerr-McGee does not contest jurisdiction provided that Staff demonstrates that the material along the Creek accidentally escaped from the site, it does recognize that there are limitations on the Commission's authority to regulate mill tailings prior to the passage of UMTRCA. *Id.* at 20

2. Fifteen pCi/g averaged over 15 cm thick layers more than 15 cm below the surface. The specified levels of contamination may be averaged over areas of 100 square meters.[19]

In view of Staff's concession that EPA's radium-in-soil standard may not be applied retroactively, we must decide whether it is appropriate guidance for the specific problem posed by the Kress Creek radiological contamination.

We begin by noting the nature of the hazard which Staff perceives. Staff testified that the principal exposure pathways from thorium and its daughters are direct irradiation and inhalation.[20] Staff counsel has indicated that the principal hazard to the present residents of the Kress Creek area is from gamma doses.[21] Staff's reply findings indicate that the possibility that houses might be built on the existing contamination many years in the future may not be overlooked,[22] although Staff's proposed findings indicate that the radium-in-soil standard was not designed to protect against that possibility.[23]

Staff relied upon EPA's statement that the radium-in-soil standard is appropriate for the cleanup of offsite vicinity properties. Staff's justification for the use of the radium-in-soil standard is set out below.

> Q8. Has USEPA stated a view as to the appropriateness of applying the 5 and 15 pCi/g standards to cleanup of offsite properties in the vicinity of Title II sites?
>
> A8. Yes. USEPA has stated in its "Final Environmental Impact Statement for Standards for the Control of Byproduct Materials from Uranium Ore Processing" (FEIS), which was prepared in support of the issuance of 40 C.F.R. Part 192, Subparts D and E, that:
>
> > We believe that the Standards (40 CFR Part 192, Subpart B) we have already published for the off-site cleanup program for inactive mills under Title I of UMTRCA would be suitable for application to off-site contamination from active mills.
>
> FEIS, Volume II, Page A.1-3. *See* also pp. A 5-36 and -37. This would include offsite thorium, as well as uranium, contamination, since the numerical standards are the same for both chains. FEIS, Vol. I, Appendix G, Vol. II, p. B 3-2.[24]

---

[19] Kerr-McGee notes that this statement should have specified radium-228 above background. Staff witnesses Cool and Shum so specified in their testimony (Tr. 469-70), and we consider the standard in that light.

[20] Shum/Cool, ff. Tr. 425, at 6.

[21] Kerr-McGee Exh. 12, Tr. 344.

[22] Staff Reply Findings at 12.

[23] Staff Proposed Finding 110 at 49.

[24] Shum/Cool, ff. Tr. 425, at 4-5.

Page B.3-2 of Vol. II contains responses to individual comments on EPA's draft impact statement and consequently does not merit great weight. However, it is evident from this reference that EPA was concerned with radon emanating from a *tailings pile*, not with the hazard posed by contamination of property in the vicinity of the pile, such as the problem posed by Kress Creek.

The response to Comment 7 — which states that the risks from radon-220 (thoron) emissions from a tailings pile are comparable to those from radon-222 emissions when the much larger source term from thoron is taken into account and which references Appendix G of the FEIS — makes clear that USEPA was focussing on a hypothetical tailings *pile* and the need for thoron flux reductions from such a pile. Similarly, review of Vol. 1, Appendix G, shows that USEPA was focussed on demonstrating the need for thoron flux reduction from a hypothetical thorium mill tailings pile. In the Kress Creek situation, there is no tailings pile and we do not find the staff reference to be helpful. We do not find any mention of the radium-in-soil standard in Appendix G.[25]

However, in Appendix G, § G.4, there is a brief discussion of gamma radiation from tailings. It states that individual doses must be assessed on a case-by-case basis because details on shielding and distance are critical in the calculation. This is directly pertinent to the Kress Creek situation. Moreover, § G.4 also makes the point that for equal concentrations, the gamma flux density and associated absorbed dose rate for the thorium series is approximately 50% greater than for the uranium series. If a radium-in-soil standard were to be used to protect the public from gamma radiation, the difference between the thorium and uranium decay series would lead to two different standards for the two *different* materials. Permissible concentrations of thorium would be less than permissible concentrations of uranium.[26]

However, it is clear that the radium-in-soil standard was not promulgated by the USEPA to control gamma exposure rates but rather to limit the inhalation exposure of people in houses to radon-222 and its daughters as described on pages 9-14 to 9-16 of the FEIS. The specification in the standard that the contamination levels should be averaged over 100 square meters reflects this fact.

[25] For this reason we do not agree with Staff that, in promulgating the radium-in-soil standard, USEPA balanced costs and benefits for radium-228.

[26] The spotty nature of the Kress Creek contamination results in low gamma doses. If this contamination were more widely distributed over the Kress Creek area, occupancy factors and consequently dose would increase. Nonetheless, a radium-in-soil standard is not an appropriate way to regulate gamma doses because the latter are easily measurable. A gamma dose limit is more straightforward.

When the risk to the public from possible inhalation of daughters of radium-226 (uranium series) is compared to possible inhalation of daughters of radium-228 (thorium series), a substantial quantitative difference is evident. The health risk resulting from exposure to a given concentration in air of thoron and its daughters is about one-third that of radon and its daughters. FEIS at G-8. Furthermore, we accept Kerr-McGee's testimony (Auxier *et al.*, Table III-1) that if a house were built on soil containing equal concentrations of radium-228 and radium-226, the concentration of thoron and its daughters in the house would be 30 times smaller than the concentration of radon and its daughters. Thus, when the differing half-lives of thoron and radon are taken into account, the overall inhalation risk resulting from building a house on soil containing thorium and radium-228 is approximately 90-fold smaller than the risk from building on soil containing the same activity of uranium and radium-226.

If a "radium-in-soil" standard were appropriate for protecting the public in the Kress Creek situation, the above quantitative differences between the thorium and uranium series could be considered. However, we see no need to do so. Staff counsel has stated that external gamma radiation is the primary mode by which members of the community using the Creek area could receive additional radiation exposures,[27] and Staff does not contest Kerr-McGee's Proposed Findings 133 and 135-140 which assert that the risk posed by inhalation of thoron emanating from Kress Creek (either outdoors or within a hypothetical house built over a concentration of 110 pCi/g) is inconsequential. The Kerr-McGee testimony on risks shows that direct gamma exposure is the predominant pathway in the dose assessment. Auxier *et al.*, ff. Tr. 591, at 20-21. We agree that any risk to the public posed by Kress Creek results from direct gamma exposures. A "radium-in-soil" standard is superfluous and inappropriate. In the next section, we examine this risk against a gamma exposure standard, based on Part 20, of 0.1 rem per year (rem/yr) above the natural ambient background.

The use of a 0.1-rem/yr criterion provides a greater degree of public health protection from direct gamma exposure than the EPA radium-in-soil standard. On page 9-16 of the FEIS, EPA estimated the residual risk of fatal lung cancer under the radium-in-soil standard as 2 in 100 for lifetime exposure resulting from living in a house built on soil contaminated with uranium. The Kerr-McGee testimony (Auxier *et al.* at 23) quotes the International Commission on Radiation Protection and the

---

[27] Note 19, *supra*.

NRC as to risk from ionizing radiation at 1.65×10^{-4} per rem. The 0.1 rem/yr criterion corresponds to a lifetime (70-year) cancer fatality risk of approximately 1 in 1000. The use of a 0.1-rem/yr exposure limit provides a greater degree of public health protection than the radium-in-soil standard by a factor of approximately 20 where the hazard comes from gamma radiation.

For all of the foregoing reasons, we reject the radium-in-soil standard as appropriate to protect health in the circumstances of this case. Findings 65 through 76 support this result. However, we reach no conclusion with regard to the appropriateness of this standard in dealing with a different situation.

PART 20 CRITERIA FOR CLEANUP

We have determined that the standards promulgated by EPA under UMTRCA are not appropriate to govern a cleanup at Kress Creek, and that Part 20 applies. Therefore, we believe it appropriate to review Part 20 to determine whether, under its standards, Kress Creek may present a hazard. We do so recognizing that Part 20 standards have not been advocated by Staff despite our calling attention to them.

In our unpublished Memorandum and Order of March 22, 1985, we noted that, in view of Staff's concession that UMTRCA was not legally applicable, the radium-in-soil standard was not immune to attack under 10 C.F.R. § 2.758. We went on to state that "we expect the proponents to justify the application of these standards to the single, unique situation at Kress Creek . . . . as opposed to the application of other standards (for example, the standards found in 10 C.F.R. Part 20)."

We recognize that Staff's choice not to advocate Part 20 standards would inhibit us from granting relief based on them. Nonetheless, Kerr-McGee did address them in its testimony, and we have concluded that they are not only applicable, but more appropriate to assess the Kress Creek risk than the radium-in-soil standard. Consequently, we believe it advisable to address them.

We began by noting that § 20.105(a) sets down the proposition that:

> The Commission will approve the proposed limits [on levels of radiation in unrestricted areas] if the applicant demonstrates that the proposed limits are not likely to cause any individual to receive a dose to the whole body in any period of one calendar year in excess of 0.5 rem.

The 0.5-rem standard is based on the recommendation of the Federal Radiation Council. The National Council on Radiation Protection and

Measurements and the International Commission on Radiological Protection made parallel recommendations. The Commission has noted that the 0.5 rem standard gives

> appropriate consideration to the overall requirements of health protection and the beneficial use of radiation and atomic energy. The Commission believes that the record clearly indicates that any biological effects that might occur at the low levels of these standards have such low probability of occurrence that they would escape detection by present-day methods of observation and measurement.[28]

Thus 0.5 rem/yr constitutes a level of exposure which is unlikely to have any visible effect on the person exposed to it.

The 0.5-rem exposure limitation is a limitation on all exposures (except natural background and medical exposures).[29] Because it must be assumed that any individual will experience doses from multiple sources, the exposure from any single source of gamma radiation, such as Kress Creek, must be less than 0.5 rem/yr.

The Commission has proposed to adopt a new Part 20. That proposal furnishes guidance as to how much less than 0.5 rem/yr any exposure from an individual source should be. Noting that it is impractical if not impossible to accurately determine the precise total dose received by any individual member of the public, proposed § 20.303(a) establishes a reference level of 0.1 rem. If a licensee can demonstrate that its operations will not result in a dose to any individual in excess of this amount, it will be deemed to be in compliance with the 0.5-rem limitation.

We believe the 0.1-rem standard to be appropriate for Kress Creek. Section 161(b) authorizes orders necessary to "protect health." Similarly, § 2.202(a) addresses potentially hazardous situations. Part 20 establishes that no individual member of the public should receive a dose at more than 0.5 rem in any calendar year. In order to ensure that the 0.5-rem standard will not be exceeded from all sources, proposed Part 20 establishes 0.1 rem as a dose level for individual sources which may not be exceeded without justification. Based on the above, we believe that 0.1 rem represents a reasonable limitation on dose resulting from the material in the Creek area which is necessary to protect health.

---

[28] Rulemaking Hearing — Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low As Practicable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents, CLI-75-5, 1 NRC 277, 280 (1975).

[29] *Id.*

THE 0.1-REM LIMITATION APPLIED TO KRESS CREEK

The significance of any particular, localized area of elevated gamma exposure rate will depend on the time period that people might be reasonably expected to be in that area, i.e., to occupy that particular locale. The health risk to an individual depends on the time-integrated or summed exposures. Thus, in examining the observed gamma radiation distributions in the Kress Creek area to determine the extent to which a hazard may exist, occupancy factors are of paramount importance because anticipated radiation doses are directly proportional to anticipated time of exposure.

Staff responded to our question[10] that occupancy factors should be considered in connection with Kress Creek, but did not offer an opinion concerning the appropriate occupancy factors that would apply to the Kress Creek properties, other than to note that the USEPA used a 75% occupancy factor for indoor exposure in the FEIS, Vol. I, at 5-2. Cool/Shum testimony at 12.

The Kerr-McGee testimony (Auxier *et al.* at 8-10) cites a report by N.A. Frigerio, T.J. Larson, and R.S. Stowe ("Thorium Residuals in West Chicago, Illinois," NUREG/CR-0413, ANAL/ES-67, 1978; Kerr-McGee Exh. 1)) as a basis for estimating an occupancy time of 200 hours per year (hr/yr) for "lawns and gardens of a sort experiencing some residential occupancy." The Board perceives this estimate of the outdoor exposure time period to be debatable. We note that Frigerio *et al.* did not estimate occupancy factors for the Kress Creek properties, but rather only made estimates for a number of locations in the City of West Chicago.

Kerr-McGee quotes Frigerio *et al.* as noting "that occupancy is inhibited simply by the relatively high fraction in inclement weather in this area." Frigerio *et al.* at 9. The term "relatively high" is subjective and provides no basis on which to judge occupancy. We note that, even if the weather is unsuitable for outdoor activities 50% of the time, outdoor occupancy might easily be 540 hr/yr and we question whether the Frigerio *et al.* estimate is sound.

Also, we consider it possible that outdoor occupancy and exposure might not be the primary risk consideration for the Kress Creek situation. As Dr. Chambers, a Kerr-McGee witness, testified, "one could postulate that there might be some external gamma radiation associated with time spent indoors." Tr. 685. Shielding or exposure reduction for

[10] *See* Unpublished Memorandum and Order of May 8, 1985

the gamma radiation fields caused by the Kress Creek materials has not been measured as a part of the record in this proceeding. For frame houses, the shielding might be roughly 10% so that the indoor exposure rate may not be much smaller than the outdoor exposure rate.[31] When outdoor occupancy of roughly 540 hr/yr or 6% of the year is compared with 75% indoor occupancy (6570 hours), it can be seen that indoor exposure rates 10 times smaller than outdoor rates would lead to dominance in the total exposure sum for the indoor exposure.

The 0.1-rem/yr criterion would correspond to a 11 microrem per hour (μrem/hr) increment above background, if continuous, year-long exposure occurred. If the background exposure is taken as 9 μrem/hr, indoor exposure with 75% occupancy should be limited to 24 μrem/hr to meet the 0.1-rem criterion. Review of the ORAU report shows that there are only a few residential properties where the exposure rate borders on 24 μrem/hr. Outdoor exposure rates measured by ORAU are well below the 0.1-rem criterion on any reasonable occupancy rate. Findings 77 through 83 support these conclusions, while Findings 22 through 29 describe Kress Creek and Findings 30 through 64 describe the radiological surveys and their results.

Because no party has addressed § 20.1(c) which admonishes that doses should be "as low as is reasonably achievable," we do not consider whether the gamma doses resulting from Kress Creek meet this standard. However, our review of the record indicates that there are a few limited areas of relatively high gamma exposure rates which might be cleaned up with a minimum of expense and disruption.

Furthermore, no party has addressed the questions of the size of the population which might be exposed to gamma radiation emanating from Kress Creek or the realistic (as opposed to maximum acceptable) doses that that population might receive. Nor has any party addressed the costs and disruption incident to a cleanup to ALARA standards.[32] Therefore no balancing is possible under § 20.1(c).

Because of the above, we express no opinion whether, had Staff chosen to proceed under Part 20, some relief might have been appropriate. This record does not foreclose that possibility.

---

[31] *See Long Island Lighting Co.* (Shoreham Nuclear Power Station, Unit 1), LBP-85-12, 21 NRC 644, 773 (1985).

[32] Kerr-McGee has submitted uncontroverted testimony on the economic and environmental impacts, as well as industrial risks, of cleanup to the radium-in-soil standard.

Findings of Fact

BACKGROUND

1. The Lindsay Light Company began processing thorium ores at West Chicago, Illinois, in the 1930s. In 1958, American Potash & Chemical Corporation purchased the Lindsay Light Company, including the West Chicago site. In 1967, Kerr-McGee acquired the site through a merger with American Potash. Rare Earths FES at xi.

2. The Rare Earths facility consists of three portions: a factory site (8 acres), where processing occurred; a disposal site (27 acres); and an intermediate site (8.4 acres), which is between the factory and disposal site and has not been used for site operations. Horn *et al.* Testimony at 3.

3. The disposal site currently contains two major solid waste residue piles and five disposal ponds. *Id.* at 5-6.

4. The railroad right-of-way runs parallel to and just west of the west boundary of the entire site. The right-of-way is markedly elevated above the surrounding topography. *Id.* at 4-5.

5. The facility operated from 1932 to 1973. Initially, the facility primarily produced thorium nitrate for use in incandescent light mantles. The facility also produced rare earth materials for a variety of industrial uses including polishes, chemical manufacture, catalysts, and television phosphors. *Id.* at 8. A major portion of the activities at the site were related to the production of thorium pursuant to government contracts. Rare Earths FES, Appendix H at H-4.

6. With the passage of the Atomic Energy Act of 1954, production of thorium at the facility became subject to federal regulation. At all times since May 1, 1956, the facility has been licensed by the Atomic Energy Commission or its successor, the Nuclear Regulatory Commission. Rare Earths FES at xi.

7. The process used for thorium and rare earths production at the facility produced two waste materials. These wastes were deposited on site. One resulted from the ore digestion process and was a solid sand-like residue. The other was composed of liquid wastes from a number of processes and contained dissolved salts and suspended solids. The solids settled out on the bottoms of the facility's sumps and percolation ponds. These sediments were periodically dredged from the ponds and sumps and placed on a sludge pile near the ponds. Both these waste materials, which contain quantities of thorium and thorium daughter products, remain on the disposal site pending resolution of *Kerr-McGee Chemical Corp.* (West Chicago Rare Earths Facility), Docket No. 40-2061-ML. Horn *et al.* Testimony at 10.

8. A storm sewer runs to the east of the factory site (under Factory Street), jogs west under the intermediate site, and then continues south under the west edge of the disposal site just inside its western boundary. It then proceeds under property not owned by Kerr-McGee to its discharge point into Kress Creek. *Id.* at 4, 12.

9. The storm sewer outfall is approximately 400 meters south of the southwest corner of the disposal site. Kress Creek flows generally south from that outfall for approximately 2000 meters to its confluence with the West Branch of the DuPage River. *Id.* at 5-6. Staff Exh. 1 at 2.

10. Neither Kerr-McGee nor its predecessors have ever been cited for any violation relating to the discharge of thorium into Kress Creek. Tr. 409.

CAUSE OF THE CONTAMINATION

11. The Staff believes that contamination may have reached the Creek through the storm sewer. Staff suggests that the material could have reached the sewer by (1) drainage from roof or yard drains, (2) overflow of process liquids from an onsite sump, (3) erosion or physical displacement from the tailings pile to a manhole on the disposal site, or (4) overflow or drainage from the percolation ponds. Horn *et al.* Testimony at 15-18.

12. The Staff relies on documentary evidence for its theories of how the thorium-bearing material reached its present location on or in Kress Creek. *Id.*; Tr. 365, 373, 380. No one on the Staff has personal knowledge of how materials got from the site to the Creek. Tr. 358.

13. The amount of material that may have come from roof drains cannot, by itself, explain the volume of material in the Creek. Tr. 365.

14. The specific location of the yard drain or drains and the nature of any connections to the sewer are subject to some uncertainty based on documentary records. Tr. 370-71. However, the NRC Staff has personally observed one yard drain on the Kerr-McGee site. Tr. 370-71; 410.

15. Liquid process wastes met the radiological limits for discharge to a sanitary sewer established by AEC and NRC regulations according to documentary records of 1972. Tr. 380, 391-92. However, thorium can concentrate in the environment. Tr. 410.

16. Radiological contamination of the groundwater under the site, which would be the consequence of drainage from the percolation ponds, has not been shown. Tr. 405-06. The Staff nevertheless believes that this is a possible pathway for thorium materials to have entered the storm sewer leading to Kress Creek. Tr. 411.

17. Movement of thorium-containing materials from the tailings pile to the sewer by way of a nearby manhole is a possible pathway for entry of material into the storm sewer outfall. However, a berm, which was constructed in 1957 and is located over the storm sewer, directs runoff from the waste residue piles toward a depression to the south. Resp. Exh. 3, Horn *et al.* Testimony at 4. Runoff water forms a pond to the south of the manhole. Tr. 397-98. The manhole is covered by a solid plate that has never been known to have been removed. Tr. 394-96.

18. A railroad crosses over Kress Creek in the vicinity of the storm sewer outfall. Kerr-McGee suggests the possibility that contamination entered the Creek as a result of a release from trains bringing ores to the site, but offered no direct evidence to substantiate this. No records of spills of thorium ores into the Creek from trains exist. Tr. 408.

19. Material that fell off trucks may have washed into the West Chicago storm sewers and been deposited in Kress Creek. Tr. 414, 416-17. This material could have been coming to or leaving the site. Tr. 418. The Staff has no evidence indicating this. Tr. 417.

20. There is no facility within 50 miles of the Kerr-McGee site that now processes or that ever processed thorium-bearing materials. Horn *et al.* at 19-20.

21. The quantity of solid waste (tailings plus pond sediments) produced in the West Chicago plant was approximately proportional to the ore fed to the process. Losses to residues were 20 to 25% of total oxide input. The plant processed 10,000 tons per year (tons/yr) of monazite sands during peak production years between 1954 and 1958, about 5000 to 6000 tons/yr between 1958 and 1963, and about 2000 to 2500 tons/yr before 1954 and after 1963. The ore fed to the process from 1954 to 1973 was about 77% of the total ore used from 1936 to 1973. The solid wastes on the disposal site are predominantly from operations during the period after the plant was licensed by the Atomic Energy Commission. The contamination along the Creek, in part, occurred during the period the Rare Earths facility operated under AEC license. *Id.* at 14-15; Staff Exh. 4 at 13, 31.

KRESS CREEK

22. Kress Creek is a small, spring-fed flood plain stream. It has major surges during storms. Tr. 575. Its bottom is relatively stable and its sediments are stabilized. Tr. 576.

23. The Creek floods frequently during heavy rainfall and Spring flows. Kerr-McGee Risks Testimony at 16; Tr. 583, 584. The apparent

flood control area above the storm sewer may minimize the amount of flooding that occurs. Tr. 584.

24. The land in the immediate vicinity of the storm sewer outfall is predominantly a thicket. This thicket continues for some 200 meters downstream from the outfall. Salamon Testimony at 8, Exh. A.

25. The next 600 meters downstream consist of a residential community. Houses are typically about 30 meters from the Creek with landscaped backyards that abut the banks. *Id.*

26. Except for the Nicheren Shoshu Temple (NST) and a few houses near the Creek's confluence with the River, there are no other residential areas close to the Creek between the storm sewer outfall and the River. *Id.* Staff Exhibit 1 (Figs. 4 through 7) shows the location of houses in relation to the Creek.

27. South of the residential area, there is a park that is owned and operated by the West Chicago Park District. The park consists predominately of open fields, shrubs, and occasional tree stands. The park borders the Creek for approximately 800 meters. Salamon Testimony at 9, Exh. A.

28. South of the park, the Creek traverses undeveloped pastureland, floodplain forest, open field, and the NST property. The Creek proceeds through this area for some 800 meters. This area includes clover, shrubs, woods, and woodland managed for hunting by DuPage County. *Id.*; Letter of August 6, 1984, to Honorable John H Frye, III, from Kelley, Drye, & Warren.

29. Approximately 60% of the Creek from the sewer outfall to the River passes through undeveloped field and forest. About 35% of the Creek from the outfall to the River is bounded by mature forest. Salamon Testimony at 9; Tr. 574.

RADIOLOGICAL SURVEYS

30. In 1974, Kerr-McGee began cleanup activities to decommission its West Chicago facility. At the request of the NRC, the Argonne National Laboratory conducted a radiological evaluation of thorium residues in the West Chicago area. The study of the Kress Creek region consisted primarily of direct radiation measurements between the sewer outfall and the River. Staff Exh. 1 at 1 (1984).

31. A 1977 aerial radiological survey by EG & G — together with soil and sediment samples collected in 1980 by the EPA — confirmed the presence of thorium in soil along the Creek. EPA found that the primary radionuclides in the soil were Th-232 and Th-228 in essentially secular equilibrium. *Id.*

32. On December 6-20, 1982, and April 4-22, 1983, Oak Ridge Associated Universities ("ORAU") conducted a radiological survey of Kress Creek. *Id.* at 2.

33. ORAU divided the Creek into 50-meter intervals between the River and a point approximately 100 meters south of the storm sewer outfall. ORAU also surveyed the DuPage River at 50-meter intervals for 200 meters upstream and downstream of its juncture with the Creek. *Id.* at 4.

34. At each interval, ORAU measured exposure rates at the surface and 1 meter above the surface at 1, 5, 10, and 25 meters from the edge of the Creek or River. *Id.* at 5.

35. Systematic boreholes were drilled at locations of direct radiation measurements. Other boreholes not part of the systematic sampling grid were also drilled at selected areas of elevated direct exposure levels. These are called biased boreholes. Radiation profiles in the boreholes were determined by measuring radiation levels at 15-30-centimeter intervals between the surface and the hole bottom. *Id.* at 5.

36. Soil samples were collected for laboratory analysis of thorium content from various depths in approximately 15% of the boreholes. *Id.*

37. The data from soil samples were used to construct a correlation between gamma exposure rate and thorium content. Thorium content of all other soils was then estimated using the correlation. Tr. 295; Staff Exh. 1, Tables 5, 6, and 7, and Fig. 1 at D-3.

38. Sediment samples were collected at 100-meter intervals in the stream channels along Kress Creek and the River, except for those areas in which rocky or gravelly bottoms prevented the collection of such samples. Staff Exh. 1 at 6; Tr. 259.

39. Thorium is the predominant radioactive material in the soil. Thorium-232 and thorium-228 were found to be nearly always in secular equilibrium. Thus, the measured concentrations of thorium (Th-232 and Th-228) are effectively the measurements of total radium (Ra-224 and Ra-228) as well. Staff Exh. 1 at 10-12; Kerr-McGee Volume Testimony at 2 n.1.

40. Radium-226 and uranium-238 are present in soils and sediments at inconsequential concentrations and are not a health hazard. Staff Exh. 1 at 10, 13.

41. Baseline thorium concentrations in the soil, according to ORAU, averaged 1.6 pCi/g total thorium (Th-228 and Th-232). *Id.* at 31 Table 1.

42. Average levels of thorium concentration reported by ORAU in the vertical soil profiles at 1 meter from the Creek edge were 26.1 pCi/g at the surface; 40.2 pCi/g at a depth of 15 centimeters; 38.9 pCi/g at 30 centimeters; 28.9 pCi/g at 60 centimeters; and, 18.7 pCi/g between 60

and 90 centimeters. *Id.* at 10. The surface values may be in error by up to 50% because of the geometry of the counting device. Tr. 323-26.

43. Thorium concentrations in the soil generally decrease with distance from the Creek edge. The concentrations decrease by approximately 50% at 5 meters from the edge of the Creek, and at 25 meters decrease to near to background. Staff Exh. 1 at 10; Tr. 234.

44. Maximum thorium concentrations were typically 15-30 centimeters deep along the banks of the Creek and River. Staff Exh. 1 at 11. The more highly contaminated material is generally buried below 15 centimeters of less-contaminated material. Tr. 246, [illegible].

45. There is considerable error in the ORAU soil concentration measurements. The 95% confidence interval around a measurement of 10 pCi/g is approximately 4 pCi/g to 30 pCi/g. Tr. 335. The 95% confidence interval around a measurement of 100 pCi/g is approximately 40 pCi/g to 170 pCi/g. Tr. 336. Any particular measurement thus has a very large error associated with it. Tr. 308.

46. Exposure rates at 1 meter above the surface averaged 28 μrem/hr at 1 meter from the Creek edge; 25 μrem/hr at 5 meters from the edge; 21 μrem/hr at 10 meters from the edge; and 14 μrem/hr at 25 meters from the edge. Staff Exh. 1 at 7. At 25 meters, average exposure rates are slightly above background. *Id.* at 8.

47. There is large statistical variation in the ORAU estimates of thorium in soil. The authors of the ORAU report had not previously estimated the magnitude of uncertainty by statistical means, and Board efforts to develop confidence intervals by examination at hearing were inconclusive. Inspection of the ORAU correlation that yielded estimates of thorium in soil leads the Board to conclude that roughly 95% of the data is clustered about the line of correlation in an interval that appears to have a width of about 1 decade on the vertical logarithmic scale. Tr. 295-312. Staff Exh. 1, Fig. 1, at D-3.

48. Exposure rates at 1 meter above the surface along the River downstream of its juncture with the Creek averaged 36 μrem/hr at 1 meter from the edge; 31 μrem/hr at 5 meters from the edge; 18 μrem/hr at 10 meters from the edge; and 20 μrem/hr at 25 meters from the edge. *Id.* at 7.

49. ORAU estimates that background gamma exposure rates in West Chicago are 8.6 μrem/hr. *Id.* A survey by another NRC contractor, Argonne National Laboratories, found a higher background. Kerr-McGee Exh. 1 at 2. The Argonne survey found that 95% of all readings were between 14 and 25 μrem/hr. The difference in reported background values could be the result of the fact that the background measurements were taken at different locations. Tr. 253, 255.

50. Thorium levels in the Creek sediment samples fluctuated from place to place from less than 0.34 pCi/g to 131 pCi/g. Staff Exh. 1 at 12.

51. Thorium concentrations decreased with depth in sediments. *Id.*

52. The sediment data characterize only the parts of the Creek bed with a sandy or silty bottom, which is a subset of the Creek bed. Tr. 260, 268. There is no evidence that thorium collects on rocky bottoms in the Creek. Tr. 315.

53. Approximately 70% of the Creek bottom is composed of gravel and hard substrate, with 30% consisting of softer sediment. Tr. 586.

54. One of 337 systematic ORAU gamma exposure measurements taken at 1 meter from the surface along the Creek exceeded 100 μrem/hr. Tr. 248, 250.

55. One of sixty-eight systematic ORAU gamma exposure measurements taken at 1 meter from the surface along the DuPage River exceeded 100 μrem/hr. Tr. 250, 251.

56. The contamination along the Creek and River is spotty and not constant or evenly distributed. Tr. 278, 279. Several additional widely scattered locations in excess of 100 μrem/hr at the surface exist further from the Creek banks; however, a substantial majority of all readings show exposure rates well below the 100-μrem/hr level. Staff Exh. 1, Table 2.

57. The biased sampling which was a deliberate search for areas having high levels of exposure showed that there are many specific sites having direct exposure rates above 100 μrem/hr and ranging upward beyond 800 μrem/hr either at the surface or 1 meter above it. Staff Exh. 1, Table 4.

58. There is no evidence that the thorium is now migrating or moving. Tr. 247.

59. During the Fall of 1985, Kerr-McGee undertook a systematic survey of gamma exposure rates for all properties in the Creek vicinity for which permission to survey could be obtained. The survey covered some 80% of the properties along the Creek. Kerr-McGee Risks Testimony, Appendix B at B-1 & n.1.

60. The properties were surveyed along a rectangular grid with a spacing of 5 feet, except that a 10-foot grid was used in certain nonresidential downstream areas. *Id.* at B-1 & n.2.

61. The total area surveyed was about 3,200,000 ft^2. The total area with gamma readings in excess of 50 μrem/hr was about 67,900 ft^2, or 2.1% of the total area surveyed. *Id.*

62. Of the area with a concentration in excess of 50 μrem/hr, 91.3% (or 1.9% of the total area surveyed) was contaminated at levels between 50 and 99 μrem/hr. Only 6.3% of the area contaminated to over 50

μrem/hr (or 0.13% of the total area surveyed) showed readings of 100 to 149 μrem/hr. Only 2.4% of the area contaminated to over 50 μrem/hr (or 0.05% of the total area surveyed) showed readings of over 150 μrem/hr. *Id.* at B-2 & Table B-1; Letter from R.A. Meserve to John H Frye, III, Esq. (May 6, 1986).

63. Locations contaminated above 150 μrem/hr had an average area of 450 ft^2. The maximum area of such a location was 600 ft^2. Kerr-McGee Risks Testimony, Appendix B at B-2.

64. Kerr-McGee's survey showed that contamination is spotty. The "hot spots" are small and discrete regions. *Id.*; Letter from R.A. Meserve to John H Frye, III, Esq. (May 6, 1986) (enclosing maps). The Kerr-McGee survey results are in reasonable agreement with those obtained by ORAU, which also show that elevated levels of radioactivity occur in relatively small and discrete "hot spots" with remaining areas contaminated at detectable but low levels. Staff Exh. 1, Tables 2, 3, and 4.

THE RISK POSED BY THE CONTAMINATION

65. The levels of radium-226 in Kress Creek are inconsequential. Staff Exh. 1 at 10, 13. Kress Creek involves radium-228. Kerr-McGee Risks Testimony at ii; Cool/Shum Testimony at 3.

66. The EPA's risk analysis for its radium-in-soil standards focuses on the risk from constructing a house on soil contaminated with radium-226. Tr. 443; FEIS, Vol. I, at 9-14 to 9-16.

67. The risk of constructing a home in soil containing radium-228 is appreciably less than the risk from constructing a home in soil containing radium-226. Tr. 445.

68. A typical home in Chicago has a ventilation rate of one air change per hour. Tr. 648. A detailed calculation reveals that, if a typically ventilated home were built on soil containing equal concentrations of radium-228 and radium-226, the concentration of radon daughters would be approximately 30 times greater than the concentration of thoron daughters. Kerr-McGee Risks Testimony, Table III-1; Tr. 649.

69. Thoron decay products have about one-third the health risk of radon decay products from inhalation. Tr. 445, 649.

70. The overall risk resulting from building a home on soil containing radium-228 is thus a factor of 90 less than the risk of building on soil containing the same activity of radium-226. Kerr-McGee Risks Testimony at 27-28; Tr. 649.

71. Appendix G of the FEIS includes an analysis of the risks to a regional population from a model tailings pile. FEIS, Vol. I, Appendix G.

72. The evaluation in the appendix is an exact counterpart to the analyses in the body of the FEIS to justify the flux standard that was adopted by EPA to govern the stabilization of a tailings pile. *Compare* FEIS, Vol. I, chaps. 5-6, *with* FEIS, Vol. I, Appendix G.

73. EPA's flux standard has an entirely different risk basis than its radium-in-soil standard. *Compare* FEIS, Vol. I, chaps. 5-6, *with* FEIS, Vol. I, at 9-14 to 9-16.

74. The situation along Kress Creek is unlike EPA's model tailings pile. The average surface concentration is approximately 20 pCi/g of total thorium, or 10 pCi/g of radium-224, rather than the 280 pCi/g of radium-224 assumed for a model pile. Tr. 474. The yearly emissions of thoron from the Creek area are approximately 1.8 x 10^3 Ci/yr, or approximately 1/200 of the emissions from the model tailings pile of 3.4 x 10^5 Ci/yr. Tr. 477. Thus, the risk to a regional population from Kress Creek is about 1/200 the risk from the hypothetical tailings pile. Tr. 478.

75. With the exception of radon-220 (thoron), all decay products of thorium-232 are solids and thus will remain as constituents of the soil. Kerr-McGee Risks Testimony at 5.

76. Thoron has a half-life of 55 seconds. *Id.*, Fig. I-1.

77. There are three major pathways by which human exposure from materials along the Creek might occur. First, those present in the immediate vicinity of the materials might be exposed to gamma radiation. Second, vegetables grown in the soil could take up thorium and its decay products, leading to exposure from consumption of home-grown produce. Third, humans could inhale thoron and its daughters. *Id.* at 6.

78. Although other potential pathways exist, such as dust inhalation or direct ingestion of soil, they are insignificant. *Id.*

79. The most probable activities in the Creek area include jogging and hiking, yard work, and backyard play. *Id.* at 7.

80. Frigerio estimated maximum occupancy for lawns and gardens experiencing some residential occupancy at 200 hours per year (hr/yr) (Kerr-McGee Exh. 1), but 400 hr/yr is not unreasonable (Tr. 658). Based on an occupancy time of 6 hours per day on all fair weather days (assumed to be 50%) for 6 months of the year we find 540 hr/yr is conservative for spatially distributed exposures such as those present here. Tr. 651-63.

81. The highest spatially averaged radiation levels appear to be found at a location 200 meters downstream on the east bank of the Creek. Staff Exh. 1, Table 2. The data given do not permit a reliable spatial average to be calculated but suggest that this average would not be

greater than 70 μrem/hr. This results in a dose of 0.038 rem/yr based on a conservation occupancy time of 540 hours.

82. The highest exposure rate measured at a single location by ORAU at 1 meter above the ground is 210 μrem/hr. Staff Exh. 1, Table 4. This results in a dose of 0.042 rem/yr based on an occupancy factor of 200 hr/yr. We accept 200-hr/yr occupancy time as reasonable for estimates related to small areas of high concentration.

83. A criterion of 0.1 rem/yr above background would correspond to an 11-μrem/hr rate, if continuous, year-long exposure occurred. Indoor exposure with 75% occupancy would meet the criterion if 15 μrem/hr were the limit, since 75% of 15 equals 11. If the background exposure is taken as 9 μrem/hr, indoor exposure rates should be limited to 24 μrem/hr.

CONCLUSIONS OF LAW

1. Jurisdiction exists under the Atomic Energy Act independently of the Uranium Mill Tailings and Radiation Control Act to require that a remedial action plan be prepared which is necessary or desirable to protect health because of the radiological contamination of Kress Creek and the West Branch of the DuPage River.

2. The radium-in-soil standard promulgated by the U.S. Environmental Protection Agency under the Uranium Mill Tailings and Radiation Control Act is not appropriate to protect health in the situation posed by this radiological contamination.

3. Part 20 of the Commission's regulations contains numerical radiological dose limitations which are appropriate to protect health in the situation posed by this radiological contamination.

4. The record in this proceeding does not demonstrate that the Part 20 numerical radiological dose limitations are exceeded as a result of this contamination.

In consideration of the foregoing, it is, this 19th day of June 1986, ORDERED

1. The Order to Show Cause issued to Kerr-McGee Chemical Corporation on March 2, 1984, is hereby dismissed; and

2. This Initial Decision shall constitute the final action of the Nuclear Regulatory Commission thirty (30) days after today unless an appeal is

taken to the Atomic Safety and Licensing Appeal Board pursuant to 10 C.F.R. § 2.762.

THE ATOMIC SAFETY AND
LICENSING BOARD

Dr. Jerry R. Kline
ADMINISTRATIVE JUDGE

Dr. James H. Carpenter
ADMINISTRATIVE JUDGE

John H Frye, III, Chairman
ADMINISTRATIVE JUDGE

Bethesda, Maryland
June 19, 1986

ATOM

In the Matter of

BABCOCK AND
(Parks Township
Volume Reduct

In this Memo
rules on the adm
dures and a sche

COMPLAINT:

The degree of
alleged initially
basis In the exe
the purpose of t
Appeal Board in
Station, Units 2 a

INFORMAL PR

The procedure
mal proceeding
directing the inst

C

AN ACT to amend the Uranium and Thorium Mill Tailings Control Act by changing Sections 5 and 15.

Be it enacted by the People of the State of Illinois, represented in the General Assembly:

Section 5. The Uranium and Thorium Mill Tailings Control Act is amended by changing Sections 5 and 15 as follows:

(420 ILCS 42/5)

Sec. 5. Legislative findings.

(a) The General Assembly finds:

(1) that a very large volume of by-product material, commonly referred to as uranium and thorium mill tailings, is located within this State, much of it in urban areas;

(2) that such radioactive materials pose a significant risk to the public health, safety, and welfare of the people of Illinois; and

(3) that the Department of Nuclear Safety, pursuant to the provisions of the Radiation Protection Act of 1990, regulates the generation, possession, use, and disposal of such materials to protect the public health and safety from the radiation risks associated with these materials and to ensure that they do not pose an undue risk to the public health, safety, or the environment; and

(4) that in addition to this regulation, it is beneficial for the State to have a policy promoting the safe and timely decommissioning of source material milling facilities that have come to the end of their productive lives and the safe and effective decontamination of areas within the State that are contaminated with uranium or thorium mill tailings.

Secretary of the Senate

Originated in the Senate

PUBLIC ACT 88-638

(a-5) The General Assembly also finds:

(1) that the Director, as represented by the Attorney General, and Kerr-McGee Chemical Corporation entered into an agreement dated May 19, 1994 and other related agreements to facilitate the removal of by-product material from the City of West Chicago in reliance upon the enactment of this amendatory Act of 1994;

(2) that the May 19, 1994 agreement is consistent with the public purpose as expressed in this Act; and

(3) that the May 19, 1994 agreement is not an agreement intended to relieve Kerr-McGee Chemical Corporation from the applicability of this Act under Section 35.

(b) It is the purpose of this Act to establish a comprehensive program for the timely decommissioning of uranium and thorium mill tailings facilities in Illinois and for the decontamination of properties that are contaminated with uranium or thorium mill tailings. It is the intent of the General Assembly that such a program provide for the safe management of these mill tailings and that the program encourage public participation in all phases of the development of this management program. It is further the intent of the General Assembly that this program be in addition to the regulatory program established in the Radiation Protection Act of 1990.

(Source: P.A. 87-1024.)

(420 ILCS 42/15)

Sec. 15. Storage fees.

(a) Beginning January 1, 1994, an annual fee shall be imposed on the owner or operator of any property that has been used in whole or in part for the milling of source material and is being used for the storage or disposal of by-product material, equal to $2 per cubic foot of by-product material being stored or disposed of by the facility. No fee shall be imposed, however, upon any by-product material moved to a facility in contemplation of the subsequent removal of the by-product material pursuant to law if the material has not been present at the facility for more than 180 days. ~~However,~~ No fees shall be collected from any State, county, municipal, or local governmental agency. In connection with settling litigation regarding the amount of the fee to be imposed, the Director may enter into an agreement with the owner or operator of any facility specifying that the fee to be imposed shall not exceed $26,000,000 in any calendar year. The storage fees assessed under this Section are separate and distinct from any license fees imposed under Section 11 of the Radiation Protection Act of 1990.

The fee shall be due on June ~~March~~ 1 of each year or at such other times in such installments as the Director may provide by rule. To facilitate the expeditious removal of by-product material, rules establishing payment dates or schedules may be adopted as emergency rules under Section 5-45 of the Administrative Procedure Act. The fee shall be collected and administered by the Department, and shall be deposited into the By-product Material Safety Fund, which is created as an interest bearing special fund in the State Treasury. Amounts in the By-product Material Safety Fund not currently required to meet the obligations of the Fund shall be invested as provided by law and all interest earned from investments shall be retained in the Fund.

(b) Moneys in the By-product Material Safety Fund may be expended by the Department, ~~subject to appropriation,~~ for only the following purposes:

(1) the costs of monitoring, inspecting, and otherwise regulating the storage and disposal of by-product material, wherever located;

(2) the costs of undertaking any necessary maintenance, decommissioning activities, cleanup, responses to radiation emergencies, or remedial action that may be necessary in connection with by-product materials;

(3) the costs incurred by the State arising from the transportation of the by-product material from a storage or unlicensed disposal location to a licensed permanent disposal facility; and

(4) reimbursement <u>to</u> ~~of~~ the owner or operator of any facility used for the storage or disposal of by-product material for costs incurred by the owner or operator in connection with the decontamination or decommissioning of the storage or disposal facility or other properties contaminated with by-product material. However, the amount of the reimbursements paid to the owner or operator of a by-product material storage or disposal facility shall not exceed the amount of money paid into the Fund by that owner or operator <u>plus the interest accrued in the Fund attributable to amounts paid by that owner or operator</u>.

<u>An owner or operator who incurs costs in connection with the decontamination or decommissioning of the storage or disposal facility or other properties contaminated with by-product material is entitled to have those costs promptly reimbursed from the Fund as provided in this Section. An owner or operator of a facility shall submit requests for reimbursement to the Director in a form reasonably required by the Director. Upon receipt of a request, the Director shall give written notice approving or disapproving each of the owner's or operator's request for reimbursement within 60 days. The Director shall approve requests for reimbursement unless the Director finds that the amount is excessive, erroneous, or otherwise inconsistent with paragraph (4) of</u>

16-Sep-94 5:20p

this subsection or with any license or license amendments issued in connection with that owner's or operator's decontamination or decommissioning plan. If the Director disapproves a reimbursement request, the Director shall set forth in writing to the owner or operator the reasons for disapproval. The owner or operator may resubmit to the Department a disapproved reimbursement request with additional information as may be required. Disapproval of a reimbursement request shall constitute final action for purposes of the Administrative Review Law unless the owner or operator resubmits the denied request within 35 days. Upon approval of a reimbursement request the Director shall prepare and certify to the Comptroller the disbursement of the approved sums from the By-Product Material Safety Fund to the owners or operators.

(c) To the extent that costs identified in parts (1), (2), and (3) of subsections (b) are recovered by the Department under the Radiation Protection Act of 1990 or its rules, the Department shall not use money in the By-product Material Safety Fund to cover these costs.

(d) The provisions directing the expenditures from the By-product Material Safety Fund provided for in this Section shall constitute an irrevocable and continuing appropriation to the Department of Nuclear Safety solely for the purposes as provided in this Section. The State Treasurer and State Comptroller are hereby authorized and directed to pay expenditures as provided in this Section.

(Source: P.A. 87-1024.)

Section 99. Effective date. This Act takes effect upon becoming law.

[illegible]
President of the Senate

APPROVED

this 9th day of September, 1994

Michael J. Madigan
Speaker, House of Representatives

Jim Edgar
GOVERNOR

D

U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REGULATORY RESEARCH

DRAFT REGULATORY GUIDE

Contact: Charleen T. Raddatz (301) 492-3745

DRAFT REGULATORY GUIDE DG-8013
ALARA LEVELS FOR EFFLUENTS FROM MATERIALS FACILITIES

A. INTRODUCTION

In 10 CFR Part 20, "Standards for Protection Against Radiation," § 20.1302(b) requires that:

> "A licensee shall show compliance with the annual dose limit in § 20.1301 by (1) Demonstrating by measurement or calculation that the total effective dose equivalent to the individual likely to receive the highest dose from the licensed operation does not exceed the annual dose limit; or (2) Demonstrating that (i) The annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed the values specified in Table 2 of Appendix B to §§ 20.1001 - 20.2401; and (ii) If an individual were continually present in an unrestricted area, the dose from external sources would not exceed 0.002 rem (0.02 mSv) in an hour and 0.05 rem (0.5 mSv) in a year."

In addition, 10 CFR 20.1101(b) requires that:

> "The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA)."

This draft guide is being developed to provide guidance on designing an acceptable program for establishing and maintaining ALARA levels for gaseous and liquid effluents at materials facilities. Materials facilities are those which are licensed under 10 CFR Parts 30, 40, 60, 61, and 70.

Additional guidance on ALARA programs can be found in other regulatory guides. While these guides deal primarily with occupational exposure and may

---

This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received complete staff review and does not represent an official NRC staff position.

Public comments are being solicited on the draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Regulatory Publications Branch, DFIPS, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Copies of comments received may be examined at the NRC Public Document Room, 2120 L Street NW., Washington, DC. Comments will be most helpful if received by January 20, 1993.

Requests for single copies of draft guides (which may be reproduced) or for placement on an automatic distribution list for single copies of future draft guides in specific divisions should be made in writing to the U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Office of Administration, Distribution and Mail Services Section.

be specific to one type of licensee, they contain programmatic information that may be useful to all licensees. They are as follows:

- Regulatory Guide 8.10, "Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable." This guide delineates the components of an ALARA program.
- Regulatory Guide 8.18, "Information Relevant to Ensuring that Occupational Radiation Exposures at Medical Institutions Will Be As Low As Reasonably Achievable."
- Regulatory Guide 8.31, "Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Mills Will Be As Low As Is Reasonably Achievable."
- Regulatory Guide 10.8, "Guide for the Preparation of Applications for Medical Use Programs." Section 1.3 and Appendix G deal specifically with ALARA programs for medical facilities.

Regulatory guides are issued to describe and make available to the public methods acceptable to the NRC staff of implementing specific parts of the Commission's regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents, or to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with them is not required.

In addition, further information can be found in Revision 1 to NUREG-0267,[1] "Principles and Practices for Keeping Occupational Radiation Exposures at Medical Institutions As Low As Reasonably Achievable" (October 1982).

Any information collection activities mentioned in this draft regulatory guide are contained as requirements in 10 CFR Part 20, which provides the regulatory basis for this guide. The information collection requirements in 10 CFR Part 20 have been cleared under OMB Clearance No. 3150-0014.

---

[1]Revision 1 of NUREG-0267 can be obtained from the NRC Public Document Room, 2120 L Street NW, Lower Level, Washington, DC.

B. DISCUSSION

This guide deals with only a part of a licensee's overall radiation protection program. Specifically, it deals with the application of ALARA in controlling gaseous and liquid effluents. In addition to controlling doses resulting from the release of effluents, licensees must implement a radiation protection program that controls dose rates in unrestricted areas to maintain overall doses to workers and members of the public ALARA and below the limits in 10 CFR Part 20. Licensees may choose to focus their evaluation of public dose to members of a critical group as suggested by the International Commission on Radiological Protection (ICRP) as a means of identifying and controlling the exposure to the individual member of the public likely to receive the highest exposure.

Some of the components of an effective radiation protection program, as required by 10 CFR 20.1101(b), include radiation exposure control, written procedures and policies, control of radioactive materials, radioactive contamination control, radioactive waste management, training, program reviews, and audits. Guidance on other facets of a radiation protection program for materials facilities is currently under development.

At the relatively low levels of radiation exposure in the United States, it is difficult to demonstrate a relation between exposure and effect. The dose limits in 10 CFR Part 20 are based on limiting dose to what is considered to be an acceptable level of risk to the exposed individual. Still, any radiation exposure may carry some risk. Thus, the NRC requires licensees to take actions, to the extent practicable, utilizing procedures and engineering controls to further reduce risk below the levels implicit in the dose limits in keeping with the principle that exposures should be as low as is reasonably achievable. This is the goal and purpose for radiation protection programs. In order to achieve this goal, licensees must control the way radioactive material is handled from receipt through disposal.

NRC licensees have taken actions to maintain doses to both workers and members of the public ALARA under the admonition contained in 10 CFR

20.1(c),[2] which requires that licensees "make every reasonable effort" to maintain doses and effluents ALARA. NRC licensees have generally reduced doses to relatively small fractions of the dose limits. Therefore, the NRC staff does not expect that most licensees will need to make significant changes to procedures, operations, and equipment in order to be in compliance with the requirements of the revised 10 CFR 20.1101(b).[2] However, for those licensees who have not previously developed a radiation protection program that includes written procedures and policies as well as a commitment to ALARA, additional steps may be necessary to demonstrate compliance with requirements now explicit in 10 CFR Part 20 to maintain doses ALARA.

C. REGULATORY POSITION

An ALARA program for effluent control to control doses to members of the public should contain the following program elements:

1. Management commitment to ALARA, including goals,
2. Procedures, engineering controls, and process controls,
3. Surveys and effluent monitoring,
4. ALARA reviews,
5. Worker training.

These program elements, while given specifically for effluents in this guide, are also applicable to the control of direct exposure.

1. MANAGEMENT COMMITMENT TO ALARA, INCLUDING GOALS

The single most critical aspect of successfully achieving ALARA in the radiation safety program is the commitment of management to maintain doses ALARA, both occupational and to the public. The licensee's radiation protection program (including ALARA elements) should be commensurate with the potential hazards associated with the licensed activity.

[2]In June 1991, 10 CFR Part 20 §§ 20.1001 through 20.2401 became effective, and compliance with these sections becomes mandatory on January 1, 1994. However, 10 CFR Part 20 §§ 20.1 through 20.601 became effective in 1957 and remains in effect until January 1, 1994, or when licensees voluntarily implement the requirements of 10 CFR Part 20 §§ 20.1001 through 20.2401, whichever is earlier.

1.1 ALARA Policy

The licensee should establish an ALARA policy that is issued and supported by the highest level of management. All employees should be made aware of the ALARA policy through training. This policy should make clear that all personnel will be responsible for ensuring that work they perform is in accordance with the ALARA policy.

1.2 ALARA Goals

To assist in demonstrating compliance with the requirements of 10 CFR Part 20, the licensee should set ALARA goals for effluents at a modest fraction of the values in Appendix B, Table 2, Columns 1 and 2, to §§ 20.1001 - 20.2401. These goals may be set independently for gaseous and liquid effluents. Past experience and effluent information reported to the NRC staff indicate that goals within a range of 10 to 20% of Appendix B values should be achievable by most licensees. However, establishing a goal is not intended as setting a precedent or a de facto limit. Goals may need to be adjusted up or down on the basis of the annual review of what may be ALARA for the particular circumstance.

If the licensee chooses to demonstrate compliance with 10 CFR 20.1301 through a calculation of the total effective dose equivalent (TEDE) to the individual likely to receive the highest dose, the licensee should set the ALARA goal at a modest fraction of the dose limit for members of the public. Experience indicates that values of about 0.1 mSv/yr (10 mrems/yr) should be practicable in most cases. Licensees need not assume worst case models when calculating dose but rather should make assumptions that will result in realistic estimates of actual dose received by the member of the public likely to receive the highest dose.

If the circumstances of a particular case are such that the licensee cannot achieve effluent concentrations less than 20% of the Appendix B values or demonstrate by calculation that the TEDE to the individual likely to receive the highest dose is less than 0.1 mSv/year (10 mrems/year), the ALARA philosophy continues to apply, and the licensee should demonstrate compliance with the requirements of 10 CFR 20.1101(b) by evaluating procedures, engineering controls, and process controls as described in Regulatory Position 2 below.

1.3 Investigation Levels

In addition to ALARA goals, the licensee should establish investigation levels at effluent values that are close to normal or anticipated release levels. If exceeded, an investigation should be initiated and corrective actions should be taken, as appropriate.

1.4 Radiation Safety Committee

For licensees that have a radiation safety committee, one responsibility of that committee should be to establish ALARA goals. The committee should meet at least annually to review ALARA goals and discuss ways of further reducing doses if necessary. Goals may need to be adjusted on the basis of the committee's review. The committee should assess short-term and long-term performance in terms of achieving the ALARA goals. ALARA goals and the results of reviews should be reported at least annually to senior management with recommendations for changes in procedures or equipment needed to accomplish the requirements of the ALARA policy as appropriate. For licensees with no radiation safety committee, the radiation safety officer should be responsible for setting, adjusting, and reviewing ALARA goals.

2. PROCEDURES, ENGINEERING CONTROLS, AND PROCESS CONTROLS

Licensees should consider available engineering options to control the release of effluents to the environment. Examples of the available options include filtration, encapsulation, adsorption, containment, and the storage of liquids for decay.

If further reductions in effluents are needed to achieve ALARA goals, modifications of facilities, operations, or procedures should be considered. These modifications should be implemented unless an analysis indicates that a substantial reduction in dose would not result or costs are considered unreasonable. A determination of reasonableness may be based on a qualitative analysis requiring the exercise of judgment and consideration of factors that may be difficult to quantify. These factors could include nonradiological social or environmental impacts, the availability and practicality of alternative technologies, and the potential for unnecessarily increasing occupational exposures.

Alternatively, reasonableness may be based on a quantitative cost benefit analysis. Preparation of an ALARA cost/benefit analysis requires the use of a dollar value per unit dose averted. The NRC staff is conducting a review and analysis of various methodological approaches to setting dollar values, and the staff recognizes that varying degrees of justification exist for a wide range of dollar values. However, the value of $1000 per person-cSv (man-rem) has been acceptable to the NRC staff and may be used pending completion of that reassessment.

3. SURVEYS AND EFFLUENT MONITORING

Licensees must perform surveys and monitoring sufficient to demonstrate compliance with the requirements of 10 CFR 20.1302. This includes the monitoring and surveys that may be necessary to determine whether radiation levels and effluents meet the licensee's established ALARA goals. These surveys should include air and liquid effluent monitoring, as appropriate, as well as surveys of dose rates in unrestricted areas.

If the licensee chooses to demonstrate compliance with dose limits to the member of the public likely to receive the highest dose by calculating the TEDE, all significant environmental pathways should be evaluated. Some of the equations included in Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," and Regulatory Guide 3.51, "Calculational Models For Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations," may be useful in performing dose assessments. However, pending the anticipated revision of these regulatory guides, the dose conversion factors should be based on the methodology described in ICRP 30, "Limits for Intakes of Radionuclides by Workers."[3]

3.1 Air Effluent Monitoring

When practicable, releases of airborne radioactive effluents should be from monitored release points (e.g., monitored stacks, discharges, vents) to ensure that the magnitude of such effluents is known with a sufficient degree of confidence to estimate public exposure. Licensees should verify the performance of effluent monitoring systems by regular calibration (at least annually) to ensure that these monitors provide reliable indications of actual effluents. Further guidance can be found in Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment."

Effluent monitoring systems should be designed in accordance with ANSI N13.1 (1969), "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities,"[4] and ANSI N42.18, "Specification and Performance of On-site Instrumentation for Continuously Monitoring Radioactive Effluents."[4]

NCRP Commentary No. 3, "Screening Techniques for Determining Compliance with Environmental Standards,"[5] published in January 1989 and the addendum published in October 1989 provide acceptable methods for calculating dose from air effluents. In addition, there are several computer codes available that perform these calculations. Licensees may use such computer codes as long as they can demonstrate that the code uses approved methods.

---

[3]Copies are available from Pergamon Press, Inc., 660 White Plains Road, Tarrytown, NY 10591-5153, Phone (914) 594-9200.

[4]Copies of ANSI standards may be obtained from the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

[5]Copies may be purchased from the National Council on Radiation Protection and Measurements, NCRP Publications, 7910 Woodmont Avenue, Bethesda, MD 20814.

3.2 Liquid Effluent Monitoring

When practicable, releases of liquid radioactive effluents should be monitored. Methods for calculating doses from liquid effluents similar to those described in NCRP Commentary No. 3 are currently under development by the NCRP. In the interim, guidance available in Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills," and Regulatory Guide 4.16, "Monitoring and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Gaseous Effluents from Nuclear Fuel Processing and Fabrication Plants and Uranium Hexafluoride Production Plants," may be useful to materials licensees in calculating doses from liquid effluents.

3.3 Unmonitored Effluents

If a licensee has release points for which monitoring is not practicable, the licensee should estimate the magnitude of the unmonitored effluents. For instance, a research hospital or university broad scope licensee might have dozens of locations where radioactive material could be released. The licensee should estimate the magnitude of unmonitored releases and include those estimated amounts when demonstrating compliance with dose limits and the licensee's ALARA goals. Unmonitored releases may be estimated based on the quantity of material used in these areas or the number of procedures performed or other appropriate methods. When practicable, unmonitored effluents should not exceed 30% of the total estimated effluent releases.

4. ALARA REVIEWS

According to 10 CFR 20.1101(c), the content and implementation of the radiation protection programs, which would include the ALARA effluent control program, must be reviewed at least annually. This review should include analysis of trends in release concentrations and radionuclide usage as well as other available monitoring data. The review should provide a documented basis for determining whether changes are needed in systems or practices to achieve

ALARA effluent goals. In addition, the licensee should review all designs for system installations or modifications to ensure compliance with 10 CFR 20.1101(b). The results of ALARA reviews should be reported to senior management along with recommendations for changes in facilities or procedures that are deemed necessary to achieve ALARA goals.

5. WORKER TRAINING

Specific training on ALARA should be provided as a part of the annual employee radiation protection training (see 10 CFR 19.12). Employees must understand the ALARA program's goals and principles for an ALARA program to be successful. Radiation protection staff should be available to help clarify the ALARA policy and its goals and to assist employees both during training and throughout the year.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this guide.

This draft guide has been released to encourage public participation in its development. Except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method to be described in the active guide reflecting public comments will be used in the evaluation of applications for new licenses, license renewals, or license amendments and for evaluating compliance with 10 CFR 20.1001-20.2401.

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. The regulatory analysis prepared for 10 CFR Part 20, "Standards for Protection Against Radiation" (56 FR 23360), provides the regulatory basis for this guide. A copy of the "Regulatory Analysis for the Revision of 10 CFR Part 20" (PNL-6712, November 1988) is available for inspection and copying for a fee at the NRC Public Document Room, 2120 L Street NW., Washington, DC, as an enclosure to Part 20.